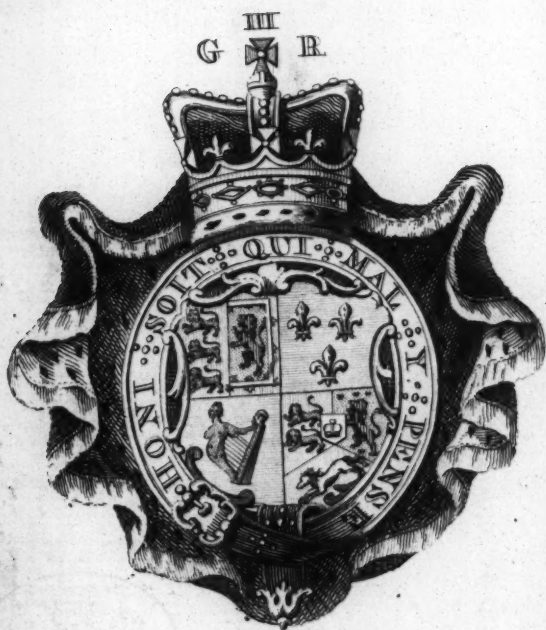
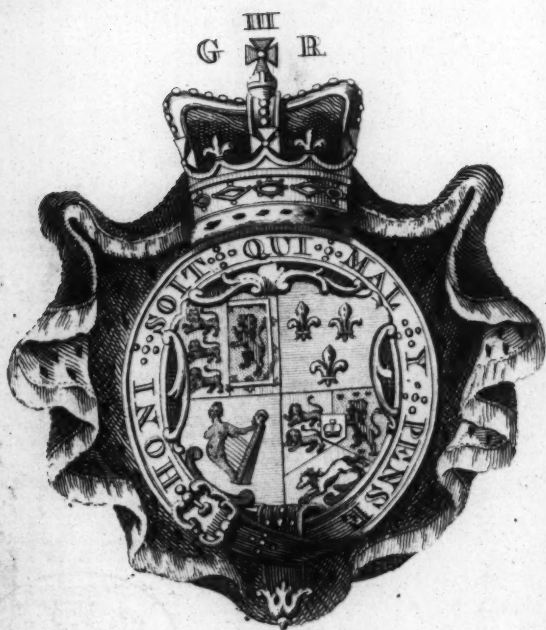






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A
COMPENDIOUS COURSE
OF
Practical Mathematicks.

Particularly Adapted to the
USE of the GENTLEMEN
OF THE
ARMY and *NAVY*.

IN THREE VOLUMES.

For the most Part translated from the TRACTS publish'd
in *French* by P. HOSTE, Professor of MATHEMATICKS
in the *Royal Academy of Thoulon*.

By WILLIAM WEBSTER.
The SECOND EDITION,
Corrected, with a few Remarks, by *Ellis Webster*.

VOL. III. containing,
I. Use of the GLOBES. | III. The THEORY of
II. NAVIGATION. | Working a Ship.

To which are added,
I. An ALPHABETICAL EXPLANATION of such Sea-Terms and
Phrases as occur in the WORK.
II. An APPENDIX, containing the DESCRIPTION and Use of
a Complete SET of CASE of Pocket-Instruments.

L O N D O N:
Printed for D. BROWNE, without *Temple-Bar*; and
C. HITCH and L. HAWES, in *Pater-Noster-Row*.
M.DCC.LI.

8





To the Right Honourable

G E O R G E,

Lord Viscount TORRINGTON,

First Lord COMMISSIONER of the
Admiralty, &c.

MY LORD,

 S a Treatise on Numbers could no where have been so properly addressed as to that eminent Master of Figures the Rt. Honourable Sir *Robert Walpole*, First Lord Commissioner of the Treasury, who has done my *Arithmetick in Epitome* the Honour of his Patronage; nor a *Collection of Mathematical Tracts on the Principles of Military Architecture*, &c. laid so rightly as at the Feet of his Grace the Duke of *Argyle*, Master-General of the Ordnance, who has likewise had the Goodness to accept it: So Your Lordship will, I hope, excuse my Ambition in Dedicating this Part of the Work, which regards the Marine, and contains an *Attempt towards a Rationale on the Practical Part*

DEDICATION.

Part of Navigation, to Your Lordship, who, with such deserved Honour, presides in the Naval Affairs of *Great-Britain*.

It is a peculiar Happiness to a Writer when his Work so naturally points out its Patron; and the Author of these Tracts, more fortunate in that Respect in his Translation, than in his Original, will (if living) rejoice to see his Performance honour'd with the Eminent Names of the Duke of *Argyle* and Your Lordship.

I have no Plea, as a Stranger, for this Address, but the Aptness of the Subject, which I hope will excuse, both to Your Lordship, and the World, this Presumption of,

MY LORD,

Your Lordship's

Most Obedient, and

Most Humble Servant,

William Webster.



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THE USE *of the* GLOBES.



Sphere or Globe is a round solid body, upon the surface whereof are drawn certain circles and figures, representing the movement and disposition of the heavenly bodies ; or the situation and extent of the Earth and Water.

There are three sorts of Spheres.

1. The Coelestial, for the Stars, &c.
2. The Terrestrial, for the Earth and Seas.
3. The Armillary, which has respect both to the one and the other.

N. B. *To make what follows the more intelligible, the Reader should have an Armillary Sphere before him.*

Suppositions and Definitions.

1. The Heavens appear like the concave surface of a globe, whose centre is the middle of the

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B

earth ;

earth ; and which continually turning round upon two of its points diametrically opposite to each other, carries about with it the stars and planets, which seem fix'd therein ; making them every day describe circles, which have the said point for their poles.

2. The two points upon which the heavens thus turn, are called, *The Poles of the World*. That which is visible to us in *Europe*, is the north, or artick pole ; the other the south, or antartick : The streight line passing from the one pole to the other, is called, *The Axis of the World*. And the circles which the stars every day seem to describe, are named, *The Parallels* of each star. Every fifteen degrees of these circles, make an hour of time.

3. Some of these heavenly bodies sensibly change their places in the heavens, and those we call *Planets*. And the circle which these stars describe by their particular movement in thus changing their places, is called, *The Ecliptick*. Those stars which do not sensibly change their places in the heavens, are called *Fixed Stars*. For the better recollection of the several fixed stars, they are reduced to certain figures, called, *Constellations* ; the twelve principal of which, are those which give names to the twelve divisions of the ecliptick, and are called, *The twelve Signs of the Zodiack*.

4. A body is said to descend, when it approaches towards the center of the earth ; but when it recedes from it, and becomes more distant, it is said to ascend. A line is said to be plumb or right to the earth, when being prolong'd it would pass through
through

through its center as AC. A line is said to be horizontal, when it is perpendicular to such a plumb or right line as DE; and when a line makes an acute angle with a plumb line as CF, it is then said to be inclined. Fig. 1.

5. In whatever place of the earth we are, we may sensibly perceive one half of the heavens; and may easily imagine a circle dividing that part which we see, from the other which we do not see; and such circle is called, *The Horizon*; the middle point of the visible part of the heavens (which is directly over our heads) is called, *The Zenith*; and the middle point of the invisible part (which is directly under our feet) is called, *The Nadir*: And as these two points answer in every place to a line plumb or perpendicular to the earth, there are therefore as many different zeniths and nadirs, and consequently horizons as there are different points upon the earth. For example, if I stand at the point A, my zenith will be Fig. 2. the point in the heavens C, my nadir F, and my horizon the circle BD. But if I am at the point K, my horizon will be HI, my zenith G, and my nadir L.

6. We call it *Day*, when the sun is in that part of the heavens which we see; but when it is in the other part invisible to us, we call it *Night*. In the same manner we call that part of the parallel which is described by any star in the visible part of the heavens, its *diurnal Arch*; the remaining part of the parallel is called its *nocturnal Arch*. That little glimmering of light which appears before or after day, we call the *Twilight* or *Crepuscle*.

PROP. I.

Of the Armillary Sphere.

1. An Armillary Sphere is composed of ten open circles, with a little ball or button in the middle, answering to the center of the earth, supported by a small wire representing the axis of the world.

2. There are six great circles, and four small ones; the great ones are, the Horizon, the Meridian, the Equator, the Zodiack, and the two Colures.

H O R I Z O N.

The Horizon is a great circle, dividing that part of the heavens visible to us, from the other part which we do not see. But there being as many different horizons as there are different places, the horizon of the sphere is therefore made moveable*. This circle is divided into 32 equal parts, answerable to the 32 points of the mariner's compass, the 4 chief of which are the north, or that point of the horizon answering to the north-pole; the south, answering to the south-pole; the east, or that point of the horizon where the sun rises, when the days and nights are equal; and the west, which

* Or rather, it should be said, the sphere is contriv'd to turn within this circle. The same thing is to be understood in the next paragraph, with regard to the meridian.

which is that point where the sun sets when the days and nights are equal. The middle points betwixt any two of these principal ones, take their names from those two they are between, as the north-east is the middle point between the north and east. The same is also to be understood of the other divisions, for we call that point the north-north-east which is between the north and the north-east, &c. And thus names are given to the 32 points of the horizon. The horizon is again divided into 360 degrees, which last division is also applied to the three following circles of the sphere. The horizon serves to shew the rising and setting of the heavenly bodies, the length of the days and nights, and the course of the winds, or points of the compass.

M E R I D I A N.

The Meridian is a great circle passing thro' the two poles of the world, and through the zenith and nadir points of each country. *Fig. 5.* It is made moveable in the sphere, to the end it may represent the different meridians of the several countries. This circle chiefly serves, 1. To divide the diurnal and nocturnal arches into two equal parts, so that when the sun is in the meridian, it is then mid-day or midnight. 2. To mark the meridian height of the stars, which is an arch of the said circle, comprehended between the star and the horizon. 3. To shew the latitude of every country, which is that arch of the meridian comprehended between the horizon of the country and the pole; or that arch of the said circle included betwixt the zenith of the place and the equator; of which we now proceed to speak.

E Q U A T O R.

The Equator is a great circle equally distant from the two poles of the world. It has divers uses, 1. When the sun is in the equator, the days and nights are equal every where, except under the poles. 2. The equator is the boundary from whence we begin to measure the latitude of places, and the declination of the heavenly bodies: For as the latitude of a country is that arch of the meridian contain'd between the equator and the zenith of the place; so the declination of a star is also that arch of the meridian included between the equator and the star. If the zenith of a country is between the equator and the north-pole, its latitude is north; but if between the south-pole and the equator, its latitude is south; the same is to be understood of declination. 3. On the equator is reckon'd the longitude of places, and the right ascension of the heavenly bodies: For the longitude of a country is the arch of the equator between the meridian of such place, and the place through which the first meridian is accounted to pass (which with us is *London*, or the pike of *Teneriff*, and with the *French* the *isle de Fer*) and the right ascension of a star is also the arch of the equator, between the first degree of *Aries*, and the meridian passing through the said star.

Note, Both longitude and right ascension are reckoned from west to east. 4. The circles daily described by the heavenly bodies, being apparently parallel to the equator, time is therefore measured by the degrees of the equator, 15 of which are equal

equal to an hour, and consequently the whole 360 to 24 hours.

Z O D I A C K.

The Zodiac is a broad Circle 16 degrees wide, through the middle of which runs the ecliptick of the sun, or that great circle *Fig. 7.* which the sun describes yearly, as it changes its place in the heavens; by its particular movement. The ecliptick cuts the equator in two points, called the *Equinoxes*, making therewith an angle of $23^{\circ} 29'$ which is the greatest declination of the sun. The ecliptick and zodiack are divided into 12 equal parts, called *Signs*; beginning from the first equinoctial point, or first degree of *Aries*, and proceeding from west to east. They have the names and figures following, viz. *Aries* ♈, *Taurus* ♉, *Gemini* ♊, *Cancer* ♋, *Leo* ♌, *Virgo* ♍, *Libra* ♎, *Scorpio* ♏, *Sagittarius* ♐, *Capricornus* ♑, *Aquarius* ♒, *Pisces* ♓. The particular day of each month upon which the sun enters each sign, is also added: Lastly, each sign is divided into 30 degrees, and the sun running through very near a degree every day from west to east, is a little more than 365 days in passing through the whole ecliptick.

C O L U R E S.

The Colures are two particular meridians, one of which passing through the equinoctial points of the ecliptick, is called the *Equinoctial Colure*: The other, passing through the two points of the ecliptick, which are farthest distant from the equator, is called the *Solstitial Colure*. They

cut the equator into 4 equal parts, which make the 4 seasons, *viz.* 1. The spring, or that part of the ecliptick between the first point of *Aries* and the last of *Gemini*. 2. The summer, or that part of the ecliptick between the last point of *Gemini* and the first of *Libra*. 3. The autumn, or that part of the ecliptick between the first point of *Libra* and the last of *Sagittarius*. 4. The winter, or that part of the ecliptick between the last point of *Sagittarius* and the first of *Aries*.

3. There are also 4 lesser circles, *viz.* the two tropicks, and the two polar circles. The tropicks are the sun's most distant parallels from the equator; that towards the north is called the *Tropick of Cancer*; and that towards the south, the *Tropick of Capricorn*. The polar circles are also parallel to the equator, and pass through the poles of the ecliptick; one is called the *Artick*, or *North polar Circle*; the other *Antartick*, or *South polar Circle*.

P R O P. II.

Of the Cœlestial Globe.

1. The Cœlestial Sphere is furnished with the several circles before described, *viz.* the horizon, meridian, equator, the ecliptick of the sun, the two colures, the tropicks, and the polar circles.

2. Through the poles of the world and the divisions of the equator, are drawn circles at every 10 or 15 degrees, which are called *Circles of Right Ascension*. And through the divisions of the meridian, at every 10 degrees, are also drawn circles parallel

parallel to the equator, called *Circles of Declination*.

3. In the same manner, through the divisions, and through the poles of the ecliptick at every 10 degrees, are also drawn circles, to which we give the name of *Circles of Astronomical Longitude*: And lastly, through the divisions of the solstitial colure at every 10 degrees, are drawn circles parallel to the ecliptick, and called *Circles of Astronomical Latitude*.

4. Every star is placed in the intersection of its right ascension and its declination; for example, to find the bright star of *Aries*, whose right ascension is $27^{\circ} 35'$ and its declination $22^{\circ} 1' N$. place the moveable meridian upon $27^{\circ} 35'$ of the equator, and that point of the globe answering to $22^{\circ} 1'$ of the meridian, betwixt the equator and the north pole, is the place of the said star; and so of all the rest.

P R O P. III.

Of the Terrestrial Globe.

1. The Terrestrial Globe is also provided with a moveable horizon and meridian; and the equator, ecliptick, the tropicks, and the polar circles, in like manner too at every 10 degrees, circles are drawn parallel to the equator, which are called *Parallels of Latitude*; and also through the poles, and through every 10 degrees of the equator, other circles which are called *Circles of Longitude*.

Note, *These circles of longitude are more commonly drawn through every 15 degrees of the equator.*

2. Every country is laid down in the intersection of its proper longitude and latitude. Thus to find the pike of *Teneriff*, whose longitude (if the first meridian be supposed to pass through *London*) is $26^{\circ} 31'$, and its latitude $38^{\circ} 32'$, bring the moveable meridian to $26^{\circ} 31'$ of the equator, and counting on the meridian from the equator northwards $38^{\circ} 32'$ under that point will be found the pike of *Teneriff*. Or, if *London* were the place you look for, whose longitude is $0'$ and latitude $51^{\circ} 32'$ bring the moveable meridian to the first point of the equator, and $51^{\circ} 32'$ on the meridian gives you the place of *London* on the globe. Thus knowing the longitude and latitude, any place on the globe may be easily found. Hereafter the manner of finding both the one and the other shall be shewn.

3. The terrestrial globe may be placed in three different situations. 1. If the equator is perpendicular to the horizon, we call it a right sphere. 2. If the equator is inclined to the horizon, we call it an oblique sphere. 3. If the equator is parallel to the horizon, we call it a parallel sphere. The people who live under the line, that is, who have their zenith in the equator, have their sphere right: Those that dwell under either of the poles (if there be inhabitants there) have their sphere parallel. All the rest of the world have their sphere oblique.

4. When

4. When the sphere is right, the horizon cuts all the parallels of the sun into two equal parts, and consequently the days are all equal to the nights. But when the sphere is oblique, the horizon cuts those parallels into two unequal parts, and therefore the days are longer than the nights in summer, and shorter in winter. Whereas the sphere being parallel, the horizon not at all cutting the parallels, but the one half being above, and the other half below, causes six months day, and six months night, to those who have the sphere in such a situation.

5. Under the equator the longest days are but 12 hours, and the further distant we go from it, the longer their days are in summer, so that under the polar circles the longest day is 24 hours, and approaching still nearer to the poles, we find one month, two months, three months of day-light, till at the poles themselves they come to six months.

6. The 4 lesser circles of the sphere divide it into five parts, called *Zones*, viz. two frigid, which are between the poles and the polar circles; two temperate, between the polar circles and the tropicks; and one torrid, betwixt the two tropicks.

7. The northern and southern hemispheres are each divided into 30 climates. We call a climate such a portion of the globe lying between two parallels of latitude, as has a month of day-light more than another, in the two frigid zones; or half an hour in the other zones. There are there-

fore 24 climates betwixt the equator and either of the polar circles; because there are 12 hours of day-light difference: And there are 6 climates betwixt each of the polar circles and its pole, because there are 6 months of day-light difference.

8. There is annexed to the globe, a moveable quadrant, call'd, *The Quadrant of Altitude*, to represent the azimuths, and the almicanures. The azimuths are great circles passing through the divisions and poles of the horizon. The almicanures are circles parallel to the horizon. The use both of the one and the other shall be shewn further on.

P R O P. IV.

Of the Use of the Sphere.

Since the intelligent reader will easily of himself discover the most part of the uses of the sphere; I shall here only set down a few, which may serve to open the way for the rest.

To render the problems on the globes the more easy, on one of the poles is placed a circle, divided into 24 hours, with an index fixed upon the end of the axis; so that in turning about the globe, the index will pass over all the hours.

1. Set the globe to the elevation of the country you are in, that is, raise the pole according to the latitude of the place, counting the degrees on the brass meridian from the pole to the horizon.

2. Observe upon the ecliptick the sun's place, and bring it under the meridian. Then will that
I
point

point of the ecliptick shew upon the meridian the declination of the sun ; and the meridian will shew upon the equator its right ascension. Before you move the globe for the following operations, set the index of the hour circle to the upper 12.

3. Bring the sun's place in the ecliptick to the east part of the horizon, and the index of the hour circle will shew the hour of the sun's rising for that day ; then moving the said point of the ecliptick to the western part of the horizon, the index will point to the hour of the sun's setting.

4. Having taken the heighth of the sun before noon, and fixed the quadrant of altitude on the zenith point ; bring the sun's place in the ecliptick to coincide with the quadrant of altitude, on the eastern side of the globe, then will the index shew the hour of the day, and the quadrant will mark the sun's azimuth on the horizon. The same may be done on the west side of the globe for the afternoon.

5. Having found the azimuth of the sun with a compass, there fix the quadrant of altitude, and bringing the sun's place in the ecliptick to the quadrant, the same point of the ecliptick will shew the sun's height on the quadrant, and the index will shew the hour.

6. The same things may be done with the other heavenly bodies, whose places you know, and many other curiosities ; as to determine the whole situation of the heavens for any given time, the rising and setting of all the stars, &c.

PROP. V.

Of the Sphere in Plano.

1. The sphere in plano is nothing else but the shadow of the several circles of an armillary sphere upon the plain of the meridian, if it were enlightned with rays perpendicular to that plain.

2. It is evident that if the circle ADC be enlightned with rays perpendicular to it,
Fig. 8. the shadow of any other circle as ABC, perpendicular to it will be their common section AC. From whence it follows, that in the sphere in plano, all the circles which are perpendicular to the meridian are expres'd by right lines: As the equator, the ecliptick, the horizon, and all the circles parallel to these.

3. It is also evident, that each point of the shadow AC, answers to each point of
Fig. 8. the circle ABC by a perpendicular line AC. From whence it follows, that to know the number of degrees between the point A and the point F of the shadow of a
Fig. 9. circle AB, the semi-circle AGB, must be described upon AB, and the perpendicular FG be drawn, so will the arch AG give the degrees of its shadow AF.

4. In the same manner, to divide the shadow of a circle AG into equal parts, draw
Fig. 10. over it a semi-circle, and dividing it into equal parts, from every division let fall perpendiculars upon AG.

5. The

5. The other circles of the globe must be expressed by ellipses; but I forbear to demonstrate that here, because it is not necessary to the following problems, which are sufficient for our present design.

P R O B L E M I.

To project the Sphere in Plano.

Prepare the meridian AGBF with its divisions, and let the points GF be the poles of the world; the line AB will be the equator, and making the arch AC $23^{\circ} 29'$, CED will be the ecliptick. CH, DH, will be the tropicks, and LN the polar circles; supposing FL $23^{\circ} 29'$, as also GL. Further, having divided the ecliptick DEC into 6 parts, of which each must be 30° ; draw through the points of the divisions the lines parallel to the equator, which will represent the signs. Lastly, divide the equator AEB into 12 parts, each of which must be 15° , and through each point of the divisions, and the two poles, draw the several ellipses, and you will have the hour-circles GNF. There should also be placed on the center E, a moveable ruler to represent the horizon, divided as above describ'd; there should also be another little ruler, so placed upon this, as always to stand perpendicular to it. The figure will make all plain. The use of this sphere is too easy, to require further explanation. It is sufficient to know, that it serves to find the amplitudes, the declination, the hour, the right ascension and azimuth of the sun, as we are going to explain it in a

manner the most universal, and which does not require the apparatus of an astrolabe, rulers, and other machines, too troublesome for carriage.

PROBLEM II.

To describe upon the Sphere in Plano, the Parallels of a Day given.

Having determined AB to represent *Fig. 12.* the equator, and CD the ecliptick; draw EH perpendicular to the ecliptick CD, and the point H will be the place of the sun on the 20th of *March* N.S. take then from H upwards towards C, as many times 30 degrees as there are months past, from the 20th of *March* to the day given; and also as many degrees as there are days above the months, and you will have the point of the ecliptick answering to the day given: For example, suppose the 23d of *May* was the day given, take 63 degrees from H to I, which will be the place of the sun on the 23d of *May*: From the point I draw IL perpendicular to the ecliptick CD, and through the point L, draw MN parallel to the equator, and you have the parallel of the given day; that is to say, the shadow of the circle which the sun will describe that day.

Note, For greater exactness, you may observe the day the sun enters into each sign, and count a degree for each day only therefrom.

P R O B L E M III.

To find the Declination of the Sun.

Having laid down the parallel of the day MN, measure with a graduated semi-circle, the arch AM, or the angle AEM, *Fig. 12.* which is the sun's declination for the day given.

P R O B L E M IV.

To find the Right Ascension of the Sun.

After having found the point L for the given day; the ellipsis FLG will cut the equator in the point O, and OE will *Fig. 13.* be the distance of the sun at its nearest approach to the equinox E; and as LR contains the same number of degrees as OE, you must find the number of degrees in LR (See *Fig. 9.*) to have the distance of the sun at its nearest approach to the equinox, which will be the right ascension of the sun during the spring, and its supplement during the summer; but during the autumn, you must add 180, and subtract it from 360 during the winter, to find the sun's *Fig. 14.* right ascension, as is plain from *Fig. 14.*

P R O-

P R O B L E M V.

To find the Point of the Horizon where the Sun will be, at any Day or Place given.

After having found the parallel MN, *Fig. 15.* for the given day; take AH the complement of the latitude of the place, and the line HEL will be the horizon of the place; and consequently the point I will be the point sought. The degrees between I and E will be the distance of the sun from the true east or west points of the world, which is the point E. This distance is called the eastern amplitude, with regard to the rising; and the western amplitude, with regard to the setting of the sun.

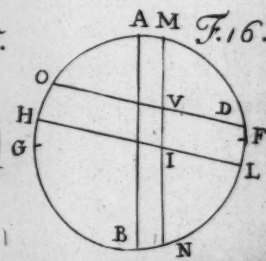
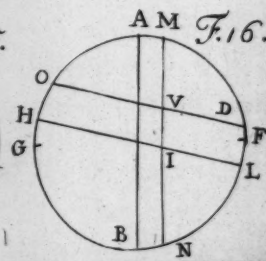
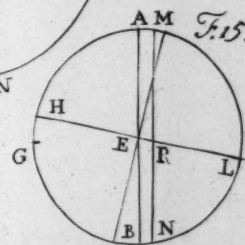
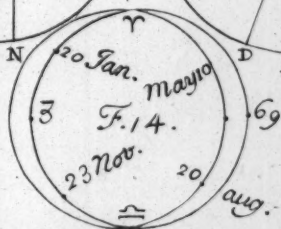
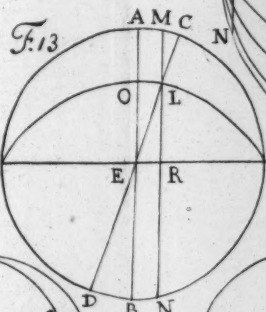
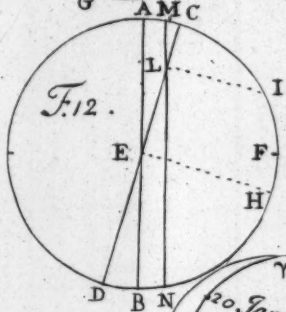
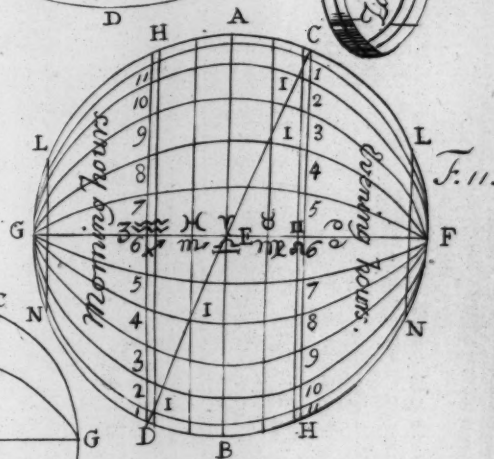
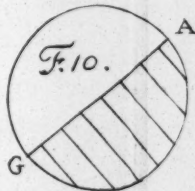
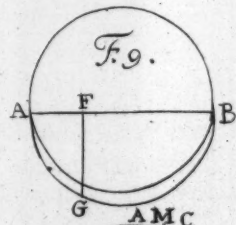
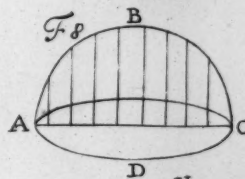
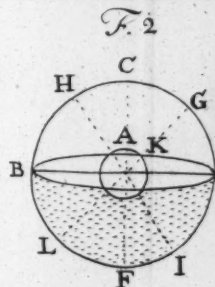
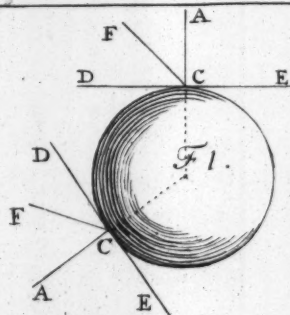
P R O B L E M VI.

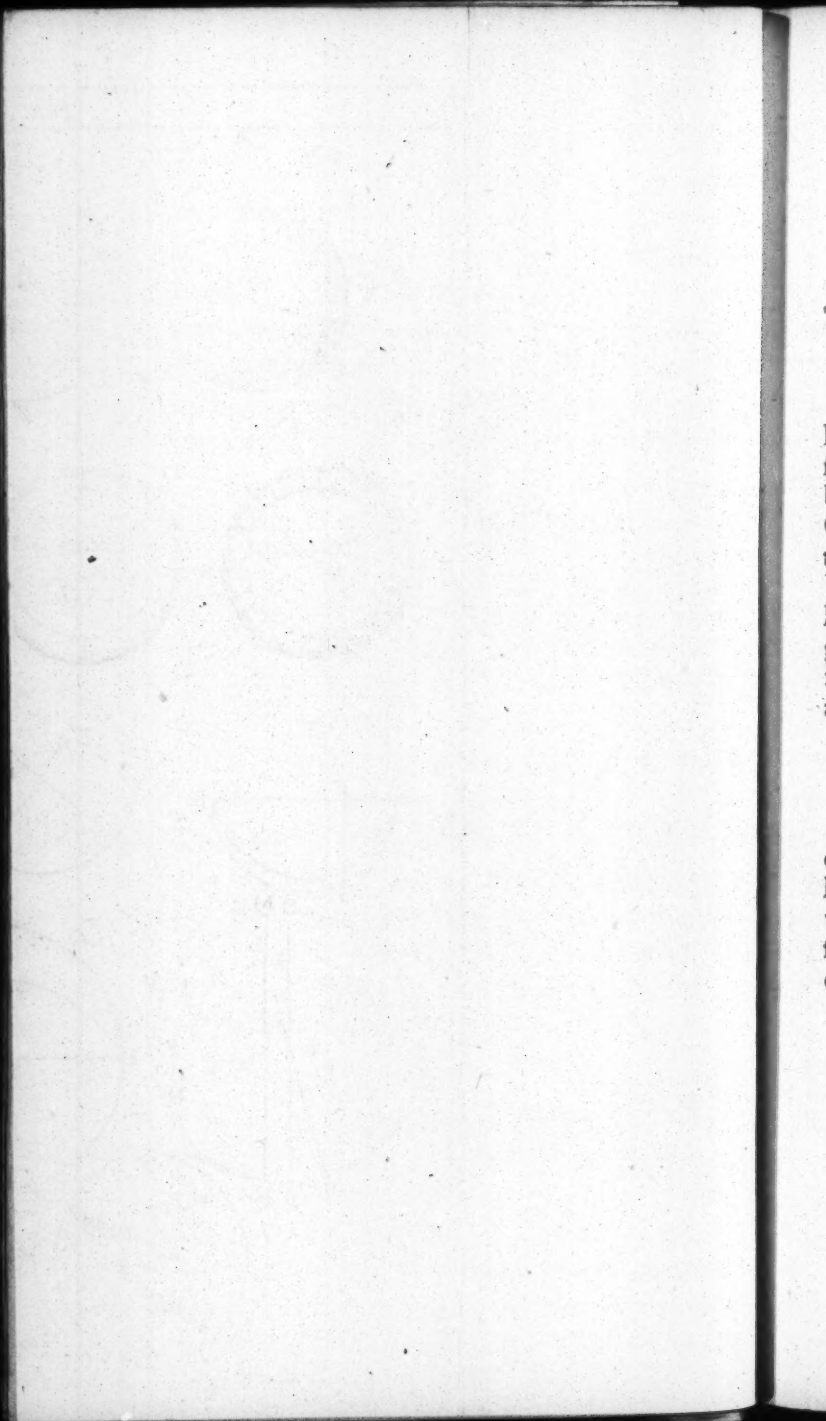
To find the Hour of the Sun's rising and setting.

In the foregoing figure the line IN will give the degrees of the parallel which the sun has run through from midnight at N, to its rising at I. In the same manner the line MI will give the degrees the sun has run through from its mid-day point M, to its setting at I. Divide then the number of those degrees by 15, and you have the hours from midnight to the sun's rising, and from noon to its setting.

P R O-

Use of the Globes.





P R O B L E M VII.

The Height of the Sun being given, to find the Hour and Azimuth of the Place given.

Resume the foregoing figure, and add to it the line OD parallel to the horizon HL, so that the arches HO and LD, will *Fig. 16.* be the height of the sun: Then will OD be the almicanure of the sun, and cutting the parallel of the sun in the point V, will give VN for the hours since midnight; VM for the hours since noon. In the same manner VO will give the degrees of the almicanure between the sun and the meridian, or the angle of the sun's azimuth with the meridian.

R E M A R K.

A very little reflection upon what has been laid down, will render the demonstration easy; and help to find out many other such like problems, by which may be discovered a general method of resolving spherical triangles, with only a ruler, a pair of compasses, and a protractor.





NAVIGATION.

NAVIGATION is a science, by which we learn to conduct a ship upon the sea with ease and safety.

We say nothing of the terms * since the persons for whom this work is intended, will learn them much easier from practice than by books.

PART I.

Of the Instruments useful in Navigation.

IT would be proper the reader should have the instruments described, before him, when he reads what follows.

P R O P.

* Tho' the author (intending this part of his work only for the use of sea-faring people) has given no explanation of sea-terms and phrases, yet being desirous to make the following Tracts intelligible to those likewise who are unacquainted with the sea language; I have annexed to the translation, an alphabetical explanation of the several terms and phrases therein made use of, which I doubt not will be acceptable.

P R O P. I.

*Of Instruments for taking Heights with a
plumb Line.*

It has been already remark'd, that the height of a star above the horizon, is an arch of a vertical circle, or of an azimuth, comprehended between such star and the horizon. Thus *Fig. 1.* the height of the star A, above the horizon CB, is nothing else but the arch AB, or the angle ADB.

1. The height therefore of the star A may be taken with a quadrant or semicircle divided into degrees: That is to say, having dispos'd the instrument in such manner upon its foot, that the plummet may play freely upon the limb, direct the sights towards the star A, and the plumb line will give the height of the star, or angle ADB.

2. In the same manner an astrolabe may be made use of, which is a graduated circle, whose divisions begin from the *Fig. 2.* point D. It is to be suspended by the point A, then will the weight B keep the line AB vertical, and the line CD horizontal. Upon the center E, a moveable ruler with two sights is contrived to turn, which being directed to the star H, the angle GED gives its height.

3. The ring AB is still a better instrument; because its divisions are more distinguishable. There is a hole pierc'd *Fig. 3.*
thro'

thro' in the point C, and as it is suspended by the point A, the weight B renders the line AB and its parallel CD vertical, and the line CE horizontal. Thus when the ray of the sun F, passes through the hole C, it falls upon the point G, and the angle GCE gives the sun's height. The whole artifice consists in dividing the semicircle EGD into 90 degrees, beginning at the point E.

These kinds of instruments are not so fit for service at sea, by reason the motion of the ship will not permit the plumb-line to settle.

P R O P. II.

Of the Fore-Staff.

1. The Fore-staff used at sea, is composed of three pieces, *viz.* a cross-piece or vane DC, a moveable sight EF, and a strait quadrangular piece, or the staff itself BA, upon *Fig. 4.* which the vane is made to slide, and so exactly fitted, as that it may always stand at right angles with it.

2. The most usual way of taking the sun's height with this instrument, is thus; place the vane CD at the end B of the staff, then applying the eye to the end C of the vane, and turning the back to the sun, move the sight-vane EF backwards and forwards till the shadow of the end D falls exactly upon the sight EF, at the same time that the eye at C sees the extremity of the horizon across the same sight EF: For then
the

the line CE is horizontal, and the angle DEC the height of the sun above the horizon; this angle is marked upon the staff at the point E , where the sight-vane is brought.

3. Another method is used, to take the height of stars which give no sensible shadow. Placing the eye at the point B of the staff, move the vane CD backwards and forwards, till the eye at B at once sees the star it is observing by the end of the vane C , and the horizon by the other end D ; for then will the line BD be horizontal, and the angle DBC will be the star's height above the horizon.

R E M A R K.

In both ways the part EB of the staff, is the tangent of the angle BCE , the complement of CBE in *Fig. 5.* and of CEB in *Fig. 4.* which is the half of the angle CBD , or CED the angle of the height found: Therefore the same divisions of the staff serve in both cases.

4. The staff BA is thus divided: Draw the perpendicular BC , equal to one half of the vane; then from the point C , describe a quadrant DF , and having set off 45 degrees from D to E , draw CE , which will cut the staff BA in the point G , and so give the division of 90 degrees, since BG will be the tangent of 45 degrees, the complement of the half of 90 degrees. In the same manner divide the half quadrant EF into 90 parts, and from the point C , drawing lines to the said divisions, your staff will be divided into degrees; for in proportion

portion as the angle GCB is augmented half a degree, the angle CGH will be diminished a whole degree.

The same method is to be pursued to lay down the minutes, every 10 of which should be distinguished, or, if practicable, every 5.

5. It would be still much more easy to divide the staff BA, by means of a scale, of the length of half the vane, divided into a thousand equal parts, and a table of tangents, whose sign total must be but 1000 parts: For taking from the scale so many parts as are found contained in the tangent of 45 degrees, and laying them down upon the staff from B to G, you have your first division of 90 degrees. In the same manner, taking from the scale the number of parts contained in the tangent of 45 degrees 30', and setting them upon the staff from the point B, you have the second division of 89 degrees, &c. Do the same for the minutes.

R E M A R K.

If the vane is small, the divisions will stand too close, and if large, many of them will fall beyond the length of the staff: They have therefore commonly four vanes, the least of which serves for the sight-vane, and gives almost all the divisions. Each vane is adapted to one particular side of the staff, to which the divisions thereon agree; and as the half of each vane, answers to the division of 90 degrees upon its correspondent side, they are easily distinguished.

P R O P.

PROP. III.

Of the English Quadrant.

1. The *English Quadrant* is composed of the staff AD, and two arches of a circle, both which have the point A for their center, viz. BC, DE; these two arches together make up a quadrant; the divisions upon BC are of 5 degrees each, but upon DE not only every single degree is mark'd, but even every two minutes: There are three sights or vanes, all perpendicular to the plane of the instrument; the first is fix'd at the point A, the two others run one upon the arch BC, and the other upon DE.

2. To use this instrument, they first fix the vane F, and then raise or fall the vane G, till the shadow of the vane F falling upon the vane A, the eye being applied to the vane G, sees the horizon a-crofs the same vane A: For then is the line GA horizontal, and the angle FAG is the height of the sun.

It will be easy to apply this instrument to the stars, nor will the Reader find much difficulty in discovering by himself the other uses of the quadrant, and of the other instruments which differ but very little from it.

PROP. IV.

Errors to be corrected in taking Heights.

1. I say nothing here concerning the parallax, wherein the error is hardly sensible.

VOL. II.

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2. The first error common to heights, is occasion'd by refraction, which makes a star, &c. appear more elevated than its true

Fig. 8. height: As supposing A the sun, E the eye, and BC the horizon, the true height of the sun will be AEC; but because the ray AD entering into the vapours of the earth, or more truly the atmosphere, is broke in the point D, and passes to the eye E, thro' the line DE, the sun will seem to be in the line EDG, and its apparent height will be DEC, therefore the angle AEG must be subtracted, to have the true height AEC. The angle AEG is greatest, when the star, &c. has the least altitude, as may be seen in the following table, wherein is set down, what ought to be deducted from the apparent height, to obtain the true.

Apparent Heights				Refractions
<i>Degrees</i>				<i>Minutes</i>
0	—	—	—	31
1	—	—	—	23
5	—	—	—	11
10	—	—	—	7
20	—	—	—	1

But according to Sir *Isaac Newton's* table since published, the refractions are found something different; for the curvature of the ray between D, and E cannot be mathematically determined, as the ray is not suddenly broke or bent at D, as shewn in the figure, but only begins there to bend, and increases bending more and more continually, 'till arrives at E, where the density of the atmosphere is

4.
sights
sidera
upper

is the greatest ; wherefore this editor hath added a part of his table, as followeth :

Heights Degrees	Refractions		Heights Degrees	Refractions	
	Min.	Sec.		Min.	Sec.
0 — —	33	45	20 — —	2	26
1 — —	27	7	25 — —	1	54
2 — —	17	8	30 — —	1	32
3 — —	13	20	40 — —	1	4
4 — —	10	48	50 — —	0	45
5 — —	9	2	60 — —	0	31
10 — —	4	52	70 — —	0	20
15 — —	3	17	80 — —	0	10

3. The second error regards the observation of the horizon at sea ; and it proceeds from that the eye of the person making the observation, being rais'd above the surface of the sea, sees the bounds of the horizon by the tangent *Fig. 9.* A B, which differs from the horizontal line A C, by the angle B A C. It would be easy to make a table of this error, with regard to the different elevation of the eye : For as E A, the radius of the earth with the elevation of the eye, is to the sign total ; so is the radius of the earth to the sign complement of the error B C A. But care must be taken, that if the height is observed with the eye directed to the object, the error of the height found be subtracted ; but if the observation is made with the back turn'd thereto, the error is then to be added.

4. The error arising from the not piercing the sights of instruments, is still more considerable ; for such sights give only the upper limb of the sun, and consequently

sometimes give the height 15' above the truth. For if the end D of the vane be obverted towards the sun A C B, the shadow G will give the height of the limb A, and not that of the center C, which is sometimes less by 15'.

P R O B. V.

Of the Mariner's Compass.

1. There are two opposite points in a loadstone, which are call'd its *Poles*; because being suffer'd to move freely, whether suspended by a thread, or floating upon cork in the water, it will turn one of these points towards the north pole, and the other towards the south.

2. The stone communicates its virtue to iron.

Having therefore a load-stone, whose north pole is A, and its south pole B, prepare a thin plate of iron, hollow'd out in the middle, and rounded at the two ends, then apply the plate to the load-stone in such manner, that the point C may be between the two poles at E, and conduct it softly along the stone, till the point C touches the pole A; then will the plate have the virtue of turning its point C towards the north pole, and its point D towards the south.

3. Prepare a Circle of paste-board, having on one side laid down upon it the points of the compass, and to the other so fasten your iron plate, that the point C may exactly answer to the north point of the card, and the point D to the south; then fixing in the center of the card, a hollow

cone of brass, and placing it upon a pivot, the card will play freely, and turn its north point towards the north pole of the world, and consequently its several divisions will mark out the whole course of the winds, each respecting its proper point.

I shall not detain the reader with the other parts of the compass, nor the manner of its use; neither do I think it needful to describe the compass of variation, or azimuth compass, since I write for persons to whom these things are very familiar.

4. I shall therefore only add, that the compass is necessary to take the plan of a place at sea, because of the motion of the vessel. The manner of using it to that purpose, is as follows. Suppose, for example, it was required to take the plan of the road $BCDEF$. *Fig. 12.* At the point A , so place your compass, that through the sights you may observe the point B , and mark the degrees of the card cut by one of the sights; do the same for the point C , and the degrees found between the points B and C will be the measure of the angle BAC . In the same manner you may find the angles CAD , DAE , EAF , then from the point G , taking also the angles FGA , EGF , DGE , CGD , BGC , you have sufficient *cognita* to form the plan of the road. See *Practical Geometry*, Prop. 4.

P R O P. VI.

The declination or variation of the Compass.

The compass has very often a sensible declination, that is to say, its north point does not always answer exactly to the north pole of the world; but tends either towards the east or west. We should therefore be often deceiv'd, if this declination, which frequently changes, were not exactly observed.

I shall only give the three ways of observing the variation (for so they term the declination of the compass) which are most easy, and most commonly used; but for the better understanding them, it would be convenient for the reader to have before him an azimuth compass.

1. When the lower limb of the Sun just appears above the horizon, set the compass of variation, so that the sights may exactly respect the sun's center, and observe the point of the compass which the sights cut. If that point is the same whereon the sun ought to rise or set (which you may know by the amplitude of its rising or setting) the compass has no variation: But if that point is farther from the north than the point whereon the sun ought to be, the compass declines so many degrees, and on the same side with the sun; if the said point is less distant, the compass declines so many degrees towards the side opposite to the sun, that is to say, N. E. in the evening, and N. W. in the morning.

2. At

2. At any hour of the day set the compass so that the shadow of a thread, joining the two sights, may fall exactly upon the middle of the chapel (for so the brass cone upon which the compass turns, is call'd) and observe how much the said shadow deviates from the north point of the compass; then seeking by the azimuth the sun's distance from the north at the time of the observation, if the two deviations are equal, there is no variation of the compass; but if they are unequal, the variation will be as above describ'd.

3. When the pole-star, and the third star in the tail of the great bear (beginning with that at the end of the tail) may be cut by a plumb line: So set the compass of variation, that the same line which cuts the two stars, may also cut the two sights of the compass, for then if the sights of the compass fall exactly upon its north point, there is no declination; but if the sights and north point do not answer each other, the difference will be the declination on the same side with the north point of the compass.

The demonstration of these practices is very evident; as well as the manner of correcting the variation, or declination of the compass.

P R O P. VII.

Of Sea Charts.

I shall say nothing of charts which some pretend to make, comprehending large parts or portions of the globe; it will be seen by what follows, how useless they are.

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1. Those charts wherein the circles of latitude and of longitude are laid down as parallels, and of equal distance, are of no worth (unless they only represent a small space, and that near the line) because they give the same extent to a degree in those parallels near the pole, as in those near the equator.

2. Charts of distance may be useful enough, if they are exactly made. They are begun

Fig. 13. by laying down the square or oblong *ABCD*, and dividing the side *AB*, which serves as a parallel, into so many equal parts as there are leagues between the two most distant places towards the east and west to be laid down in the chart; and the line *AB* so divided, will serve as a scale of leagues. Then having fixed upon some certain point as *D*, for some noted port, as *Toulon*, to lay down another, as supposing *Cape Quiel*, draw the line *DF* upon that point of the compass, which the cape of *Quiel* bears from *Toulon*, and taking upon the scale so many leagues as is the distance between the places, lay it down from *D* upon the said line to *F*, which shall be the point where cape *Quiel* is to be plac'd. The same thing is to be done for all the other places to be laid down in your chart.

There are two methods of trying the truth of this sort of charts. 1. By observing if the places laid down answer to one another by their proper bearings; for example, after having laid down *Marseilles* and *Majorca*, see if they answer each other according to the points of the compass they ought to lie upon. 2. By observing if the places which should have the same latitude, fall in the same

same line, parallel to A B. The latitudes may be laid down upon these charts, and from the latitude, or two different bearings, the distance of places may be determined.

It is further to be observ'd, that to render this sort of charts truly serviceable, they must include but a small space, and that not near the poles, especially if the latitude be laid down in equal parts taken from the line A C.

4. * Reduced charts are the best sort, the construction of which will appear in the following remarks.

R E M A R K S.

In sea charts, the meridians ought to be parallel, that the points of the compass may bear in straight lines; but then this parallelism will occasion a considerable error in making the degrees of all the parallels equal, and laying down, for example, 20 leagues in a degree in the parallel of 60, which ought to have but 10.

To remedy this error, the degrees of latitude ought to be enlarged in the same ratio, as the degrees of longitude are diminished, and the degrees of latitude will serve as a scale in such sort, that the scale increasing in proportion, as we approach the pole, the degrees of longitude, which have all the same length, will contain fewer leagues in proportion as they approach the pole.

* What the *French* call *Reduc'd Charts*, are the same which with us go by the name of *Mercator Charts*.

To find the ratio between the degrees of latitude and longitude, observe that if *AB* be taken for the radius of the equator, and *CD* for the radius of a circle parallel to the equator; the degrees of the equator will be to the degrees of the parallel, as the radius *AB* to the radius *CD*, (by the 1. 12 of *Euclid*) or as the sign total to the sign complement of the arch *AC*; and as the sign total is a mean proportional between the sign complement and the secant (by the last Prop. of *Trig.*) we conclude that the degrees of the equator, or of the latitude, are to the degrees of the parallel, or of the longitude, as the secant to the sign total. Thus taking the degrees of longitude always equal for the sign total, the degrees of latitude must consequently encrease as the secants.

5. Having prepared the rectangle *ABCD*, and divided its side *AB* into so many equal parts as you would have degrees of longitude in your chart: Draw through the divisions, lines parallel to the side *AC*, which will represent the meridians: Then having fix'd the latitude where you would have your chart begin, and laid it down on the line *AC*, for example, 36 degrees north: make *AF* one degree of longitude, the radius of a circle, from

Fig. 16. whence take the secant of 37 degrees for the line *AF*, and the secant of 38 degrees for *FG*, &c. and thus you will have the side *AC* divided into increasing latitudes. Through these divisions draw lines parallel to *AB*, and they shall represent the circles of latitude. After which it will be no difficult matter to lay down each place in the interfection of its respective longitude

gitude and latitude; and to add a compass to your chart.

A scale of increasing latitudes, may be still more exactly made with a rule of 1000 equal parts, to one degree of longitude; to lay down every 10 minutes, it will be sufficient to divide each degree into six equal parts. But to perform the thing in the most exact manner, by the help of tables and such scale of 1000 parts; From the sixth part of a degree, subtract so many parts as the secant of a degree, and 10' is less than the secant of a degree and 60', and the remainder will be the first part, or the first 10 minutes; and by adding them, you will obtain the last part: in the same manner subtracting from the sixth part of a degree, so many parts as the secant of a degree and 20' is less than the secant of a degree and 50' the remainder will give the second part, and adding the same, you will get the fifth part. All which is clear.

P R O P. VIII.

Of Tables.

In navigation we make use of several tables; but the chief are the tables of the sun's declination, those of his right ascension, of his rising and setting, of his eastern or western amplitude, and of his azimuth, or of his hour for his several heights. The construction of all which follows. Further on shall likewise be given a loxodromick Table.

- I. Borrowing from Astronomers a table of the sun's longitude for every day at noon, with the

greatest declination of the sun, which is $23^{\circ} 29'$, and in consequence thereof, supposing in
Fig. 17. Figure 17, A B C to represent the equator, E B D the ecliptick, H F I a meridian, F B the given longitude of the sun for each day, F G the declination correspondent to the given longitude, and the arch D C, or the angle F B G the sun's greatest declination; we shall be thence furnished with the following analogy, according to the 1st prop. of *Spherical Trigonometry*.

Sign total : sign B F :: sign F B G : sign F G.

That is to say, the sign total is to the sign of the sun's longitude as the sign of the greatest declination, to the sign of the declination answering the longitude given.

2. In the same manner may be found the arch B G, the nearest distance of the sun's meridian from the equinoxial point, by prop. 2. *Sph. Trig.*

*The tangent of the greatest declination F B G :
 sign total :: the tangent of the declination
 F G : sign of B G the said nearest distance.*

From which, to find the right ascension, see page 17.

3. To get the amplitude, let E B D
Fig. 18. represent the horizon, so that F B may be the eastern or western amplitude; the point F remaining the place of the sun, and the arch F G its declination, and then the angle D B C will be the complement of the latitude of the place. Which will furnish the following analogy (by prop. 1. *Sp. Trig.*)

The

The sign of the compl. of the latitude B : sign of the declination FG :: sign total G : sign of the amplitude FB.

4. For the hour of the sun's rising and setting ; it is to be observed in the same figure, that if the declination and the latitude of the place, are both towards the same pole, the arch GC will be the hour of the sun's rising, and Fig. 18. the arch GA that of its setting ; but if the declination of the sun be one way, and the latitude of the place the other, the arch GA will be the hour of the sun's rising, and the arch GC that of its setting. It will therefore be easy to say,

The tangent of the sign B the compl. of the latitude : tangent of the declination FG :: sign total : sign of GB the compl. of the arch GC, or GA.

5. Thus may be calculated a table of the hour and azimuth of the sun at all heights, for any place whose latitude is known. For let AB be the equator, E the poles of the world, G the sun, its height above the horizon GL, Fig. 19. its declination GH ; the azimuth will be the angle GFE, which may be known by the resolution of the triangle GFE, whose three sides are known, viz. GE the compl. of the declination, FE the complement of the latitude of the place, and FG the compl. of the sun's height. For by cor. prop. 5. *Sp. Trig.*

1. *Add the logarithms answering the sign of the compl. of the latitude, and of the compl. of the sun's height.*

2. *Double*

2. Double the log. of the sign total.

3. Add the log. answering to the sign of half the arch composed of the compl. of the declination, and of the difference between the latitude and the height; to that which answers to the sign of half the difference between the compl. of the declination, and the difference of the latitude, and of the height.

Subtract the first term from the sum of the other two, and the half of what remains will be the log. of half the azimuth G F E.

The same must be done to have the angle G E F, which being divided by 15 will give the hour before or after noon; only observing to put the height instead of the declination, in such sort that wherever the declination is used in the first operation, the height is to be made use of in the second, and so reciprocally.



PART

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PART II.

Of SAILING by the SIGNS.

PROP. IX.

Of a Ship's Course.

1. **W**HEN a ship sails due north and south, the line she describes is a true meridian, each degree of which is nearly 60 thousand geometrical paces.

2. When a ship sails east and west under the line, her course is the equator its self, the degrees of which are equal to the degrees of the meridians: But sailing east and west out of the line, her course describes a parallel to the equator, the degrees of which are to those of the equator, as the sign compl. of their latitude to the sign total (by prop. 7.)

3. When a ship sails upon a rumb line, which makes an acute angle with a line due north and south, her course does not form a circle, because
it

it describes a line making the same acute angle with all the meridians, which no circle can do. For example, let CD represent the equator, AB any meridian, and EF the ship's course, I say EF is not the arch of a circle.

Demonst. Since the ship keeps the same point of the compass in running through the line EF, all the angles made by the course EF with the several meridians will be equal, and moreover by the supposition acute. But if EF was a portion of a circle, it would make a right angle with the meridian passing through its poles (by sup. 6. *Sph. Trig.*) and with the other meridians, angles more or less acute, in proportion as they are nearer or farther from that.

4. The course EF will be a curve line, composed of an infinite number of right lines: To explain the matter, suppose that in parting from the point E, the ship holds a course which makes with the meridian the angle AER, some one meridian as AR, must measure this angle, and that meridian will fall perpendicular upon ER; now the angle AER, will be more acute than the angle AKR, which the ship will make with the next following meridian, if she describes the arch ER; therefore when the ship comes to the point K, she must quit the arch EKR, and fall into the line KH, so that the angle AKH, may be the same as the angle AER; but the ship's course, be it ever so small, must meet with an infinite number of different meridians, it therefore follows, that she must continually deviate from the circle ER, and

and those that succeed it, and that her course must be composed of an infinite number of lines, of which each will be part of the ship's keel, and consequently a right line.

R E M A R K.

A ship's course deviates more from the equator, or approaches less towards it, than if it described a great circle; because in order to make the angles equal, the course must approach something towards the nearest pole. For supposing *G* the place of departure, when the ship comes to the point *L*, continuing the great circle, the angles would become less acute; and consequently to keep them equal, the ship must leave the arch *LE*, and fall into *LM*, which will carry the course towards the pole *B*. It was said, that the angles which any one circle makes with the meridians, would become less acute in proportion as they approach the equator, or the line; because in approaching the line, they become more distant from that circle with which they make a right angle, or whose poles or most distant points are in the equator, upon which the poles of all the meridians fall.

P R O P. X.

Of the Loxodromick Triangle.

Let us suppose the course *AB* composed of an infinite number of right lines, making the same angle *CAB* with all the meridians: We may then imagine an infinite number of right lines *CD*, perpendicular
to

Fig. 21.

to the meridians in the points C, which with the parts of the meridians CA, likewise right lines, will form an infinite number of rectangled triangles ACD, right-lined and similar to each other, which will furnish us with the following reflections.

1. All the bases AD of these triangles make up the ship's course; all the sides AC make up the arch AL, or the ship's advance in latitude; and all the sides CD make up a mean arch between AF and EB, or the ship's advance in longitude.

2. All the bases AD of the triangles ACD, are to all the sides AC, or to all the sides CD; as any one base AD, to one side AC, or one side CD; so that giving to one base AD, the value of all the bases; and to one side AC, or CD, the value of all the respective sides; by the resolution of the right lined and rectangled triangle ADC, we obtain the resolution of the loxodromick triangle ALB.

PROP. XI.

Of a Ship's reckoning.

1. To make a judgment of a ship's way, we must regard the force of the wind, the number of sails, and the manner in which they are set, but above all must be considered, the rapidity of the water passing along the sides of the vessel; all which with good experience may enable a man to make a tolerable reckoning, especially in a ship he has before tried.

2. The

2. The use of the *Log* is very good. It is a piece of wood of half a foot long, and two inches broad, cut into the shape of a boar, as AB, underneath which is fixed a little lead by way of ballast; this log is fastened to a line by two cords, one of which is fastened at the point A, and the other at the point B is only held by a pin thrust into a hole, out of which it may easily be recovered. The log being thus prepared, when they would judge by it the ship's way, they throw it into the sea over the stern, and veer out the line as the ship advances to the length of 20 fathoms; observing by a half-minute glass the number of fathoms run out in that time; if then the number is 25, they conclude the ship makes one league an hour: For if 30" gives 25 fathoms, 60' or an hour will give 3000 fathoms, or one league, the ship then makes so many leagues an hour as the log runs out 25 fathoms in half a minute. It will therefore be easy to divide the log line in the following manner: Measuring 20 fathoms from the log, there place a white mark, as visible as may be; then at the end of 6 fathoms and $\frac{1}{4}$, place a mark for $\frac{1}{4}$ of a league; and at 6 fathoms and $\frac{1}{4}$ further, a mark for $\frac{1}{2}$ a league, &c.

3. I shall not stop here to consider those machines with wheels, which some authors have proposed for the same purpose. The sight of the sea its self is sufficient to shew their uselessness.

PROP. XII.

Of the difference of Latitude.

The difference of latitude between the place of departure, and that of arrival, may be found several ways.

1. Take the sun's height at noon, and to the complement thereof, add the sun's declination for the time, if it be on the same side of the equator with your zenith, and if it be less than the said complement, the sum shall be the latitude of the place where you have taken the altitude: But if the declination of the sun be on the other side of the equator, it must be subtracted from the complement of the sun's height, to find the latitude of the place.

To demonstrate this rule, let us suppose AB the equator, G the zenith, CD the horizon, *Fig. 23.* the arch AG will be the latitude of the place; and if we suppose the sun at the point H , the arch HG will be the complement of its height, and HA will be its declination; but if the sun be supposed at the point F , the arch FG will be the complement of its height, and FA will be its declination.

Demonst. It is evident, that if the sun be on the same side as the zenith, that is to say, if it be at the point F , the declination AF ought to be added to FG , the complement of the sun's height, to give the latitude AG . On the contrary, if the sun be on the other side the equator at the point H , its declination HA , ought to be subtracted from

HG

H G, the complement of its height to obtain the latitude A G.

It may happen in the torid zone, that the zenith and the sun may be both on the same side of the equator; but the sun's declination may be greater than the complement of his height; as for example, if the sun be at the point G, and the zenith at the point F; in that case F G, the complement of its height, must be subtracted from G A its declination, to have the latitude F A.

2. The same thing may be done by such stars, whose declinations are known.

3. When the pole star, and the third star in the tail of the great bear, reckoning from the end, may be cut by a plumb line, take the height of the pole-star, and if it be above the other, subtract $2^{\circ} 22' 40''$ or add the same quantity if it be below, and you will obtain the height of the pole, or the latitude of the place *.

* By reason of the variation of the pole-star's height in its present approximation towards the pole, which at a mean ratio is accounted about $19'' \frac{1}{2}$ yearly, the quantity to be added to, or subtracted from the altitude of the pole-star, to obtain the true elevation of the pole, is $2^{\circ} 2' 12''$ on or about the 22d of Sept. 1749. $2^{\circ} 1' 52''$ on the 22d of Sept. 1750. instead of $2^{\circ} 22' 40''$ as above; but this variation is also various at different times in each year, by the earth's annual motion having a sensible velocity compared with that of light, whereby this star appears on the 21st of June $20''$ too far off the pole in any position, and on the 21st of Dec. as much too near, as Mr. Gardiner, in his practical surveying improved, page 106, has rightly observed.

4. Seve-

4. Several tables may be made for correcting the height of the pole ; but one of the most useful is that which is composed of the height of the neighbouring stars, when they are found equal with the height of the pole *.

I omit the other methods of discovering the latitude by taking altitudes, because they are not so proper for use at sea.

P R O P. XIII.

Of the Longitude.

This is a problem which has hitherto been sought in vain, I mean to find the longitude at sea, with the same ease and certainty as the latitude.

1. Some have thought to find it by means of an exact pendulum, which being set to the meridian of their departure, may keep the exact time of their course, so that observing the hour at the place of their arrival, and comparing it with the hour of the place of their departure shewn by the pendulum, they thereby may see exactly the difference of the meridians ; for, say they, if the hour found at the place of arrival, is earlier than the hour shewn by the pendulum, divide the

* The table in this place mentioned (though inserted in the original) is here omitted, by reason of the above-hinted variations of the pole-star ; and as the other stars are likewise more or less subject to such variations, there can be no fixing of certain allowances for any duration, which must render such table useless.

difference of the time by 4 minutes, and the quotient will give the number of degrees made eastward in the course. But besides the difficulty of getting a pendulum not to be affected with the ship's motion, and the trouble of finding the hour exactly at sea; the smallest error will be found considerable, because 1 minute of time gives 15 minutes of longitude.

2. Those who would make use of the moon's longitude, or the satellites of Jupiter to the same purpose, succeed still worse: Though indeed by the immersions and emersions of the first satellite of Jupiter, the longitude of a place may be found ashore, where there is opportunity of frequently repeating the observation.

3. There remains therefore no means more certain for finding the longitude, than by the resolution of the loxodromick triangle.

P R O P. XIV.

Of the Angles of the loxodromick Triangle.

1. The angle opposite to the ship's way is right, and the angle opposite to the difference of longitude is given by the compass, being the angle of the rumb, or the angle made by the ship's keel with the meridian (by prop. 10). For which purpose the box of the compass is so disposed, that the black line thereof may answer exactly to the ship's head; and so the rumb answering the said black line, is the line of the ship's course, and the angle which this rumb line makes with the meridian, or the arch between the said black line, and

the meridian upon the compass, gives the angle opposite to the longitude.

It is to be observed, that each rumb line or point of the compass gives an angle of $11^{\circ} 15'$, therefore multiplying the points of the compass between the black line and the meridian by $11\frac{1}{4}$, the product gives the angle opposite to the difference of longitude.

2. Care must be taken to correct the variation, that is, it must be added, or subtracted, as occasion requires, to the angle given by the compass; there are many ways of doing this, but the most easy is to turn the black line of the compass in proportion, to starboard or larboard of the ship's head, on the side the variation lies; for then the black line will give the rumb, or point of the compass corrected.

PROP. XV.

To resolve the loxodromick Triangle.

The loxodromick triangle, which may be taken for a right-lined rectangled triangle, may be resolved, if so much of its angles or sides are known, as are necessary for its determination; and by this resolution, we obtain the angles and sides unknown.

SECT. I.

Departing from the latitude of 40° N. and being arrived at 42° by a N. N. E. course, it is required to find the distance sailed, and the difference of longitude. That is to say, in the loxodromick triangle ABC, wherein the angle B is right, the difference of latitude

Fig. 24.

tude AB, and the angle of the rumb BAC are known; and the course AC, and the difference of longitude CB are required.

1. Multiplying the 2 degrees, the advance in latitude, by 60 miles, and the side AB is found to contain 120 miles, and multiplying the 2 points between N.N.E. and the north point by $11\frac{1}{4}$ the angle BAC is found to be $22^{\circ} 30'$, then form the following analogies;

Sign C, comp. of $22^{\circ} 30'$: 120 miles :: sign total B : the miles of the course AC 136.

Sign C, comp. of $22^{\circ} 30'$: 120 miles :: sign A : the miles of the longitude BC 52.

2. If you would reduce the miles of longitude BC into degrees, observe that these miles are run upon the different parallels between 40° at the departure, and 42° at the arrival, and therefore without any considerable error, you may suppose them run upon the parallel of 41° a mean proportional between 40 and 42. To reduce them then into miles of the equator, correspondent to the miles run upon the parallel of 41° , use the following analogy.

Sign comp. of 41° : sign total :: 52 miles of the parallel 41° : miles of the equator 69.

And thus you will find $1^{\circ} 9'$ for the difference of longitude.

S E C T. II.

Departing from the latitude of 40° N. and arriving at 42° , after sailing eastward 136 miles, 'tis required to find upon what point of the compass the course was held, and what the difference of longitude.

In the same triangle ABC we say,

136 miles contained in the base AC : sign total
 :: 120 miles contained in the line AB : sign of
 the angle C , compl. of the angle A .

Afterwards the difference of longitude is found as in the preceding section.

S E C T. III.

Departing from the latitude of 40° N. and having sailed 136 miles on a N. N. E. course, the difference of latitude, and the difference of longitude are required.

In the same triangle ABC we say,

Sign total B : 136 miles AC : : sign C compl. of
 A : difference of latitude AB 120 miles, or 2° .

The longitude CB is found as in Sect I.

S E C T. IV.

If the longitude and latitude be known in degrees, the point of the compass and length of the course may be found. For in the triangle ABC , the miles contained in the line AB may be found, by multiplying the degrees of the difference of the latitude by 60 miles; and further, the miles of the difference of longitude may be found, by multiplying the given degrees by 60, which will give the miles of the equator answering to the miles of the line BC ; then to find the miles of the line BC form the following analogy.

Sign total : sign comp. of the mean parallel between the departure and arrival : : the miles of the equator : miles of the line CB .

After having thus determined the miles of the line AB , and of the line BC , form the following analogies.

Miles

*Miles of AB : miles of BC :: sign total : tangent
of the angle of the rumb A. Then,
Sign of the angle A : miles of BC :: sign total
: miles of the course AC.*

REMARKS.

1. The same thing may be done with the longitude as with the latitude, since the longitude is given in miles, and not in degrees.

2. When the latitude of the departure, and that of the arrival, are one south, and the other north ; it requires two operations, of which the one shall take for the difference of latitude, the distance from the departure to the line, and the other shall include the rest. Also if the course be given, it must be divided as the latitude, by this analogy ;

*Miles of the whole difference of latitude : miles
of the whole course :: the miles of the latitude
in the first operation : miles of that part of the
course.*

3. When a Ship has made several different courses, it is easy to reduce them to one, after having seen, by the resolution, what each gives with respect to the four cardinal points ; for adding together all that tend towards one point, and subtracting therefrom whatsoever tends to the contrary point ; the remainder will be the true difference in longitude and latitude, from whence may be deduced the true course, and the point of the compass or rumb line answering the several Courses. See the following example.

D 2

N.

			N.	S.	E.	W.
1	Course	Degrees	2	0	1	0
2	- - - - -		0	3	2	0
3	- - - - -		4	0	0	5
Sum			6	3	3	5
			3			3

Value of the Courses 3° North 2° West.

S E C T. V. C O R R E C T I O N S.

It often happens, that after you have resolved the loxodromick triangle (by Sect. 3.) with respect to the reckoning made of the ship's way, and the rumb line given by the compass, you may find, by some observation of an altitude, a latitude different from that found by the said resolution; and as an observation by an altitude is more certain, than either your reckoning, or the compass; either the one, or the other, or both, are to be corrected in the following manner. 1. If the course failed on is very near to a due north and south line, the reckoning is corrected by making the resolution by Sect. 1. 2. If the course failed on be nearly an east and west line, we keep to the latitude and distance, and correct the rumb line by Sect. 2. 3. If the course failed on is nearly N. E. and S. W. or S. E. and N. W. we first correct the distance by Sect. 1. then taking a mean distance between that of the reckoning, and that given by the correction, and by this mean distance, correct the course or rumb line. The reason of these practices is easily discoverable.

P A R T



P A R T III.

Of SAILING without regarding the SIGNS.

P R O P. XVI.

Of sailing by the help of Tables.

1. **T**HE loxodromick table shews under each rumb the difference in longitude, and the distance answering to each difference in latitude.

2. The table consists of but seven columns ; seven rumb being sufficient to distinguish the whole compass, and by the help of this table, may be performed all the operations before done by the signs. For if we allow, for example, one degree of difference in latitude by the N. N. E. look in the column which gives 22 degrees 30' for the rumb, the distance answering to one degree of latitude, to wit, 65 miles, will be the distance sailed ; and the 24' of longitude opposite thereto, is the difference of longitude. In the same manner having sailed 60 miles by the N. E. by N. I look in the column of the third rumb for 60, and I find over

D 3

against

against it 33' for the difference of longitude, and 90' for the difference of latitude.

3. Regard must be had to the latitude of the departure in the usage of this table, and subtract that which goes before, from that which follows in the table, to find what you look for; for example, having departed from the latitude of 40' N. and being arrived at the latitude of one degree N. after having sailed 103 miles, I run through the columns of rumb till I find one, where the distance answering to 40' subtracted from one degree, *viz.* 20', is 103 miles, and I find it to be the column of the seventh rumb, or of the E. by N. if I sailed on the east side. In the same manner I subtract the longitude answering to 40', from that answering to one degree, and the remainder is $1^{\circ} 40'$ for the difference of longitude.

4. The construction of this Table is easy; for having found (by Sect. 1.) the miles which 10' in latitude gives under each rumb for the longitude, and for the distance, we set down twice the number for 20', three times for 30', &c. and then reduce the miles of longitude into degrees.

5. Those tables which give the value of degrees of each parallel are not to be neglected: Their construction will appear, from what has been before said, in the seventh proposition.

A LOXODROMICK Table.

A LOXODROMICK Table.																				
Latitude.	1. Rumb. 11° 15'		2. Rumb. 22° 30'		3. Rumb. 33° 45'		4. Rumb. 45° 0'		5. Rumb. 56° 15'		6. Rumb. 67° 30'		7. Rumb. 78° 45'							
	Long. D. M.	Courfe Miles	Long. D. M.	Courfe Miles	Long. D. M.	Courfe Miles	Long. D. M.	Courfe Miles	Long. D. M.	Courfe Miles	Long. D. M.	Courfe Miles	Long. D. M.	Courfe Miles						
0 10 0	2	10	0	4	11	0	7	12	0	10	14	0	15	18	0	24	26	0	50	51
0 20 0	4	20	0	8	22	0	13	24	0	20	28	0	30	36	0	48	52	1	41	103
0 30 0	6	31	0	12	32	0	20	36	0	30	42	0	45	54	1	12	78	2	31	154
0 40 0	8	41	0	17	43	0	27	48	0	40	57	1	0	72	1	37	105	3	21	205
0 50 0	10	51	0	21	54	0	33	60	0	50	71	1	15	90	2	1	131	4	11	256
1 00 12	12	61	0	25	65	0	40	72	1	0	85	1	30	108	2	25	157	5	2	308

Note, These Longitudes answer to the meridional Difference of the Latitudes, and the Miles in the Courses to the proper Difference of the Latitudes, as they are more truly

PROP. XVII.

Of sailing by the Quadrant.

The *Quadrant of Reduction*, (as it is called by the *French*) or *Sinical Quadrant*, is nothing else but a great square divided into several small ones, upon which may be found all sorts of right-lined rectangled triangles, with their sides divided into equal parts. The construction will appear plain from the figure ; only take notice that the scale *EF*, is a
Fig. 25. scale of increasing latitudes, or of secants, whose radius is equal to one of the equal parts of the quadrant. The nine lines drawn from the center *A*, represent all the rumbes of the wind ; the line *AC* serving for the north and south, and the line *AB* for the east and west.

S E C T. I.

Having sailed between the 36th and 40th degrees of north latitude, and having advanced 85 miles towards the east, it is required to know the degrees of longitude answering the said 85 miles ; or, which is the same thing, it is required to find how many miles of the equator are equal to these 85 miles : And this is what is called reducing the miles of longitude, to miles of the equator.

There are two ways of resolving this question by the quadrant.

1. Take upon the line *AC*, so many parts as there are degrees of latitude between the departure and arrival, *viz.* 4, and you will have *AK*, then extend the compasses upon the scale *EF* from 36 to 40, and carry that extent from *A* to *N* ; then counting upon the parallel *KL* 85 parts to *L*, reckon-

reckoning 8 to each division of the quadrant, and the line AL cutting the parallel NM in the point M , gives upon NM , the miles of the equator, answering to the miles of the parallel, *viz.* 104 equal to $1^{\circ} 44'$. The demonstration is founded upon this, that the line AK will be to the line AN , as the sign total to the secant; or as the sign complement to the sign total; and consequently, KL will be to NM , as the miles of the parallel, to the miles of the equator (by *Prop. 7.*)

2. Extend the thread of the quadrant from A to the 38th degree of the arch BC ; because 38 is the mean between 36 and 40, then counting upon the line AB , 85 parts to the point H , reckoning 8 parts to each division of the quadrant; the parallel HI cutting the thread in the point I , will give the miles of the equator upon IA ; since in the triangle AHI , the side HA is the sign complement of the mean parallel 38, and IA is the sign total; accounting therefore 8 parts to each division of IA , you will find 104 miles or $1^{\circ} 44'$.

3. If you would change the degrees of longitude into miles, first reduce them into miles of the equator, which are measured upon the line MN , or AI , to have the lines KL , or AH , in reversing the operation.

S E C T. II.

Sailing from the latitude of 36° N. and having run 120 miles upon a N. W. course, it is required to find the difference in longitude, and in latitude.

1. Reckon upon the line AC 120 parts from A to E , allowing 6 parts to each division of the
D 5
quadrant.

quadrant. Then having extended the thread from A to E, set it off upon the line AD which represents the N. W. and it will give the point F, and the rectangle triangle AFG will represent the loxodromick triangle, whose side AG will be the difference in latitude, and the side GF the difference in longitude; allowing therefore 6 parts to each division of these sides, you will find 85 miles, or $1^{\circ} 25'$ for the difference in latitude, and 85 miles for the difference in longitude, which you may reduce into degrees (by the prec.)

S E C T. III.

Sailing from 36 degrees of north latitude, and having run 120 miles towards the east, it is found by an observation, that the ship is arrived in $37^{\circ} 25'$ N. it is required therefore to find the rumb, and difference of longitude.

I. Reduce the difference of latitude, which is $1^{\circ} 25'$ into miles, which will be found 85, and reckoning them upon the line AC, from A to G, accounting 6 to each division; reckon likewise 120 upon the same line to E, and extending the thread to E, move it about till it cuts the parallel GF in the point F, so shall you have the loxodromick triangle AFG, whose angle GAF of 45° , will give you the N. W. rumb line, and the line GF will give you 85 miles for the difference in longitude, which may be reduced to degrees (by Sect. I.)

S E C T. IV.

Sailing from 36 degrees of north latitude, and 120 degrees of longitude, a ship is to be brought
to

to a place in the latitude $37^{\circ} 25' N.$ and in the longitude of $97^{\circ} 39'$, it is required to find her course and distance. Reduce both the longitude and latitude into miles, and you will find 85 miles answer both to the one and the other, which you are to number upon the line AC for the latitude to the point G, and for the longitude, from the point G upon the parallel GF to the point F; so shall the line FA be the distance, viz. 120 miles, and the angle FAG will give the rumb line or course, viz. N. W.

S E C T. V.

Departing from 36 degrees of north latitude, and having sailed to $37^{\circ} 25'$ upon a N. W. course, it is required to find the distance sailed, and the difference in longitude. Reckon the miles of the difference in latitude, viz. 85, upon AC to G, the parallel GF cutting the N. W. rumb in the point F, gives FA for the distance sailed, and FG for the difference in longitude.

R E M A R K S.

1. There is nothing particular with respect to corrections, upon the quadrant.

2. The analogies may be all worked on the quadrant, without recourse to the table of signs: For example,

To find the amplitude, there is given the following analogy.

*The sign compl. of the latitude : sign total : : sign
of the declination : sign of the amplitude.*

D. 6

Supa

Supposing then, that we were to seek the amplitude in a place whose latitude is 38° , and that the sun's declination was 10° , extend the thread from A to the 38 degree of the arch BC, and taking CR of 10° , the parallel RO will cut the thread in the point O; transfer AO upon AP, and the parallel PT shall cut the arch BC in $12^\circ 33'$, which will be the amplitude. The reason of which is, that in the operation 38 G, the sign compl. of the latitude, is to 38 A the sign total, as QO, the sign of the declination, to AO, or AP, which will consequently be the sign of the amplitude (by 4. 6. *Euc.*)

3. In the same manner may be done those analogies, where the tangents and secants are made use of. For example, suppose this analogy,

Tangent of the sun's greatest declination : tangent of the declination of 10 degrees :: sign total : sign of the sun's distance at its nearest approach to the equinox.

Extending the thread through the 10° of the arch BC to get the tangent XB, and having transferred it upon the point Y, so that it may pass through $23^\circ 29'$, which is the sun's greatest declination, I find the parallel XZ cuts in the point Z, and the parallel ZV cutting the arch BC in the point V, will give VC for the arch sought. For so the tangent YB of $23^\circ 29'$ will be to the tangent XB, or ZS of 10° , as the sign total AB, to the sign SA, or V to that which will consequently be the arch sought (by 4. 6. *Euc.*)

P R O P.

PROP. XVIII.

Of sailing by Charts.

The same rules before given, concerning the chart of distance, may be applied to the reduced chart with more ease and certainty in taking the scale of latitude.

S E C T. I.

Departing from the point A, and having made two degrees to the north, *Fig. 26.* and 240 miles to the west, the place of arrival is required. The 2° reduc'd, make 120 miles, which taken upon the scale, are to be laid down from A to B northwards, upon a line parallel to a line N. and S. then taking upon the scale 240 miles, lay them down westward, upon a line parallel to a line E. and W. and you will find the point of the arrival C: So that the line AC will be the distance sail'd, and the rumb line upon which the course was made.

S E C T. II.

Departing from the point A in the latitude of 48° N. and having made a N. W. course, by an observation at noon, the latitude is found to be $48^{\circ} 45'$ N. it is required to find the place of arrival. Take 45 miles from the scale, and laying them down due north, you will find the point D, from whence drawing the line DE to the west, and from the point A the line AE to the north-west, the intersection E will be the place sought.

S E C T.

S E C T. III.

Departing from the point A, and having made 150 miles upon a N. N. W. course, the point of arrival is required. Take 150 miles on the scale, and lay them down on a line parallel to the N. N. W. and you will find the point F, the place of arrival.

S E C T. IV.

Departing from the point A, after having sail'd 130 miles, it appears by an observation, that the ship has advanced 30' towards the north, it is therefore required to find the place of her arrival. From the point A, lay down 30 miles due north to G, and draw G H due E. and W. then taking 130 miles, with that distance from the point A, make an arch cutting the line G H in the point H, which point H will be the place of arrival.

Note, The arch is made to the east or west, according as the course was held.

S E C T. V.

Being within sight of land, the point A is found to bear S. E. and the point B east; it is required to find the place of observation. Thro' the point A draw a line parallel to the S. E. and through the point B a line parallel to the line due east and west, and the point C, where the two lines intersect, will be the station or point of observation.

S E C T. VI.

In the same manner, if we were at 130 miles distance from the point A, and at the distance of 85 miles from the point G; from the point A describe

describe an arch with the radius of 130 miles, and from the point G, another with the radius of 85 so will the point where the arches intersect each other, give the station.

R E M A R K S.

These operations are easily perform'd with a pair of compasses; for if one point be run along any line, the other point will describe a line parallel thereto, since the compasses will keep the distance they are set to, which distance may be look'd upon as a line perpendicular to that upon which one of the points runs.

I say nothing of keeping a journal, since the Court has prescrib'd a certain method, which all are to follow; besides that my design is not to offer every thing that relates to navigation; but only what more immediately depends on the mathematics, otherwise several large volumes would hardly be sufficient.

P R O P O S I T I O N the last.

Of Tides and Currents.

By the Tide, we mean that flux and reflux of the sea, which is perceptible upon the coasts of the *Mediterranean*; but much more sensible on the several coasts of the Ocean. The tides then, are that rising and falling of the sea, which is observable twice every lunar day, under the following circumstances. 1. The waters are forc'd towards the shoars, during 6 hours before high tide, and this motion of the Waters is called the *Flood*; in like manner they retreat again for 6 hours before low water, and this last motion is called the *Ebb*. 2. High tide does not happen at the same time in all places; but each place has a particular time for its tide.

3. The

3. The time of the tides is not according to the hours of the sun, but according to the hours of the moon, and as the lunar hours are later every day by 48', the tides are in the same proportion of time later. 4. The tides are highest at the full and new of the moon, at the times of the equinoxes, and most especially at the autumnal equinox.

C O R O L L A R Y.

To determine the time of high tide at any place for each day, two things are to be known. 1. At what hour of the moon, the tide comes to that place. 2. What hour of the sun answers to that lunar hour for each day.

S E C T. I.

Of the Situation of Ports.

1. The situation of a port is that point of the compass, shewing the hour of the moon when high tide happens in such port. Pilots distinguish the hours of the moon by the points of the compass, beginning by the north and south, upon which they place mid-day and mid-night, allowing to each point of the compass $\frac{3}{4}$ of an hour. Thus when it is said that *Brest* (or *London*) is situate N. E. and S. W. 'tis understood that high tide happens there at the third hour of the moon.

2. To find the situation of a port, it must once be observ'd, at what hour high tide happens, and then see what hour of the moon answers that day to the said hour observ'd, as shall be shewn below. For example, the 16th of *April* 1729, I observe at *Brest* (or *London*) that high tide happen'd at 2 hours $\frac{1}{4}$, and I know that that day 2 hours $\frac{1}{4}$ answers

swers to 3 hours of the moon; therefore I conclude, that the situation of *Brest* (or *London*) is 3 hours, or N. E. and S. W.

S E C T. II.

Of the Hour of the Moon.

The hour of the moon is the same with that of the sun at the time of new moon; losing every day 48' or $\frac{2}{3}$ of an hour. Knowing therefore the number of days since new moon, we easily know what time the lunar hours are behind the solar. For example, if the moon is 6 days old, multiply 6 by $\frac{2}{3}$, and you will find 4 hours $\frac{2}{3}$, or 4 hours 48', the time the moon has lost with respect to the sun, whence you may conclude, that noon by the sun answers to 7 hours $\frac{1}{3}$ of the moon.

S E C T. III.

Of the Moon's Age.

By the Moon's age, we mean the number of days passed since the new moon. To determine the moon's age, we must suppose as follows:

1. That the lunar month is shorter than the solar, nearly by one day, and consequently the lunar year falls short of the solar year by above eleven days.

2. That the year before the birth of Christ, a new moon happen'd upon the first of *March*; but the year after, the new moon fell out 11 days before the first of *March*; nor did the new moon happen again upon the same day, till after a revolution of 19 years: Thus every 19 years, beginning from the year before the birth of Christ, the new moon falls upon

upon the first day of *March*; and these 19 years make up one compleat revolution of the moon.

3. The moon's age cannot exceed 30 days; therefore in every calculation of the moon's age, 30 must be thrown out as often as it is found.

4. The Epact is the moon's age at the beginning of *March*; it arises therefore from the addition of 11 days to the moon's age each year.

5. The Golden number is the number of years pass'd since the last revolution of the moon.

6. To find the golden number, add 1 to the current year, and dividing the sum by 19, the remainder shall be the golden number. For example, to find the golden number for the year 1729, divide 1730 by 19, and the remainder will be 1 for the golden number.

7. To find the epact, divide the golden number by 3, and if 0 remains, the epact is the same with the golden number; if there remains 1, add 10 to the golden number, and if there remain 2, add 20, and the sum (rejecting 30, if exceeding that number, as above directed) will accordingly be the epact. For example, to find the epact for the year 1729, divide the golden number of the year, *viz.* 1 by 3, and as the remainder is 1, add 10 to 1, the golden number, the sum is 11 for the epact. The reason this rule is founded upon is, that as the epact increases every year 11 days, and the golden number 1 day, therefore to the golden number must be added so many times 10, as there are unites above 1; but as every 3 years make 30, which must be deducted, it is better not to add the tens till after you have thrown out all the threes.

8. Having

8. Having the epact, to find the moon's age for any given day, to the epact add the number of months pass'd since *March*, and the number of days pass'd of the current month. Thus to find the moon's age for the 6th of *July* 1748; to the epact 11 add 4 for the months pass'd, and 6 the given day of the current month, and you will find 21 for the moon's age.

S E C T. IV.

Of the Time of high Tide.

Having the moon's age, and the situation of the port, the time of high tide is thus found: multiply the moon's age by 4, and divide the product by 5, the quotient gives the hours, and multiplying what remains by 12, you will get the minutes, which time being added to the situation of the port, gives the time of high water. For example, to find the time of high tide at *Brest* (or *London*) for the 6th of *July* 1729, multiply the moon's age, which is 6 days (after having deducted 15 days, which brings the moon to the full, and the tide to the hour of the sun, as at new moon) by 4, the product will be 24, the first part of which is 4 hours, and the remainder multiplied by 12, gives 48', adding therefore 4 hours 48' to 3 hours, the situation of *Brest*, I find the time of high tide for the said day, 7 hours 48'.

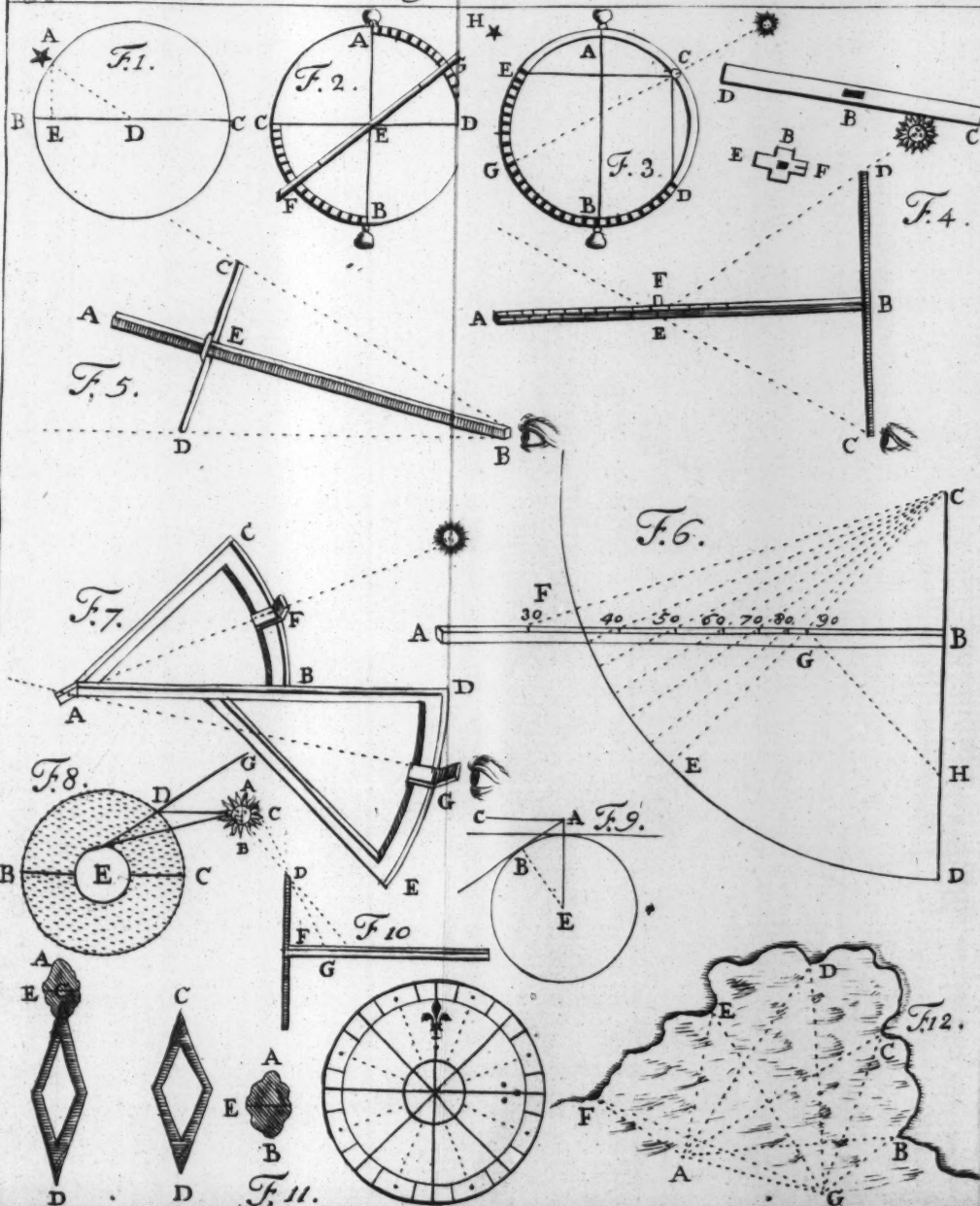
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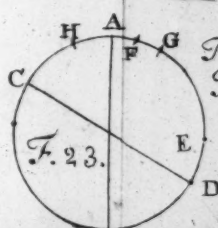
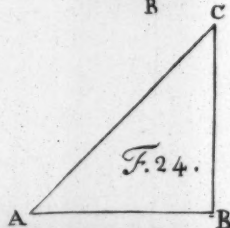
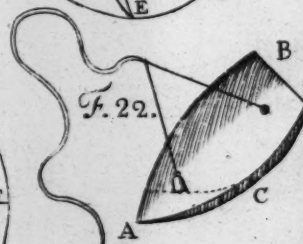
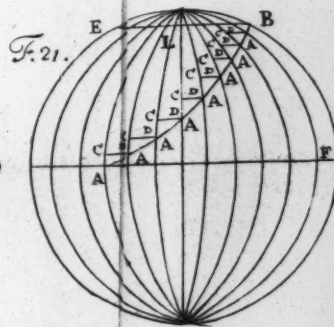
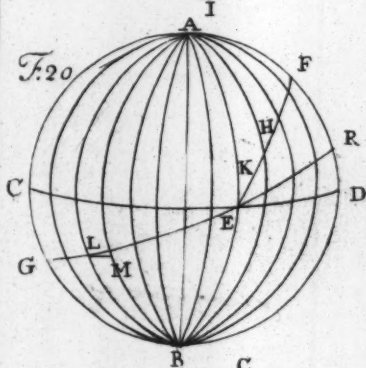
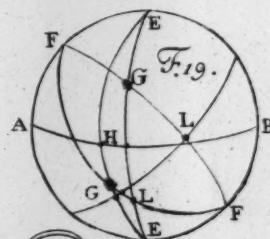
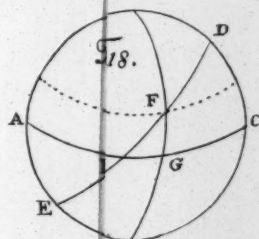
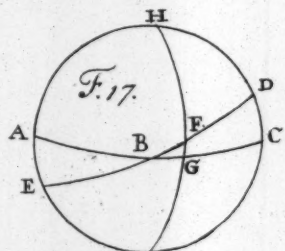
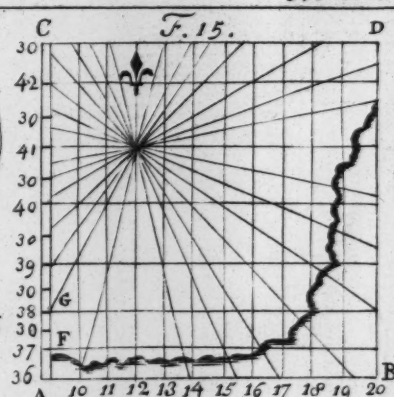
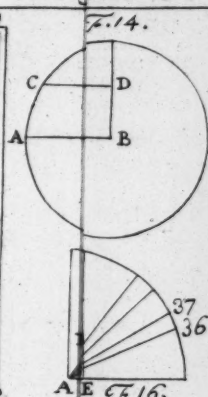
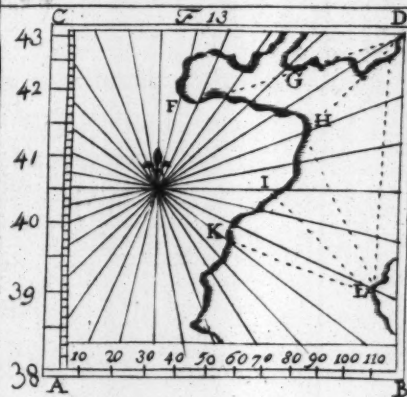
Of Currents.

We oftentimes attribute to imaginary currents, the error arising from the wrong disposition of the coasts in charts, as in the gulf of *Lions*, where the cape of *Quiel* is really much more westward

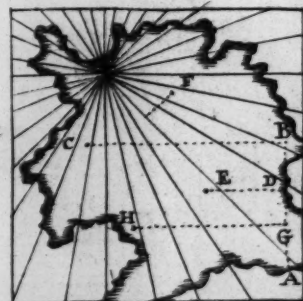
westward than it is laid down; nevertheless we cannot deny but there are currents, and more especially near land; and that it is of the utmost importance to have a due knowledge of them. It is no great difficulty to judge of them when within sight of land; but out at sea the most easy method is, to set out the boat, and throwing out a heavy grappling or other considerable weight, with as much line as possible, the boat, as if at anchor, will veer with the wind, if there be no current; but if there be a current, and little or no wind, the boat will then drive with the current, and plainly enough shew which way it sets,





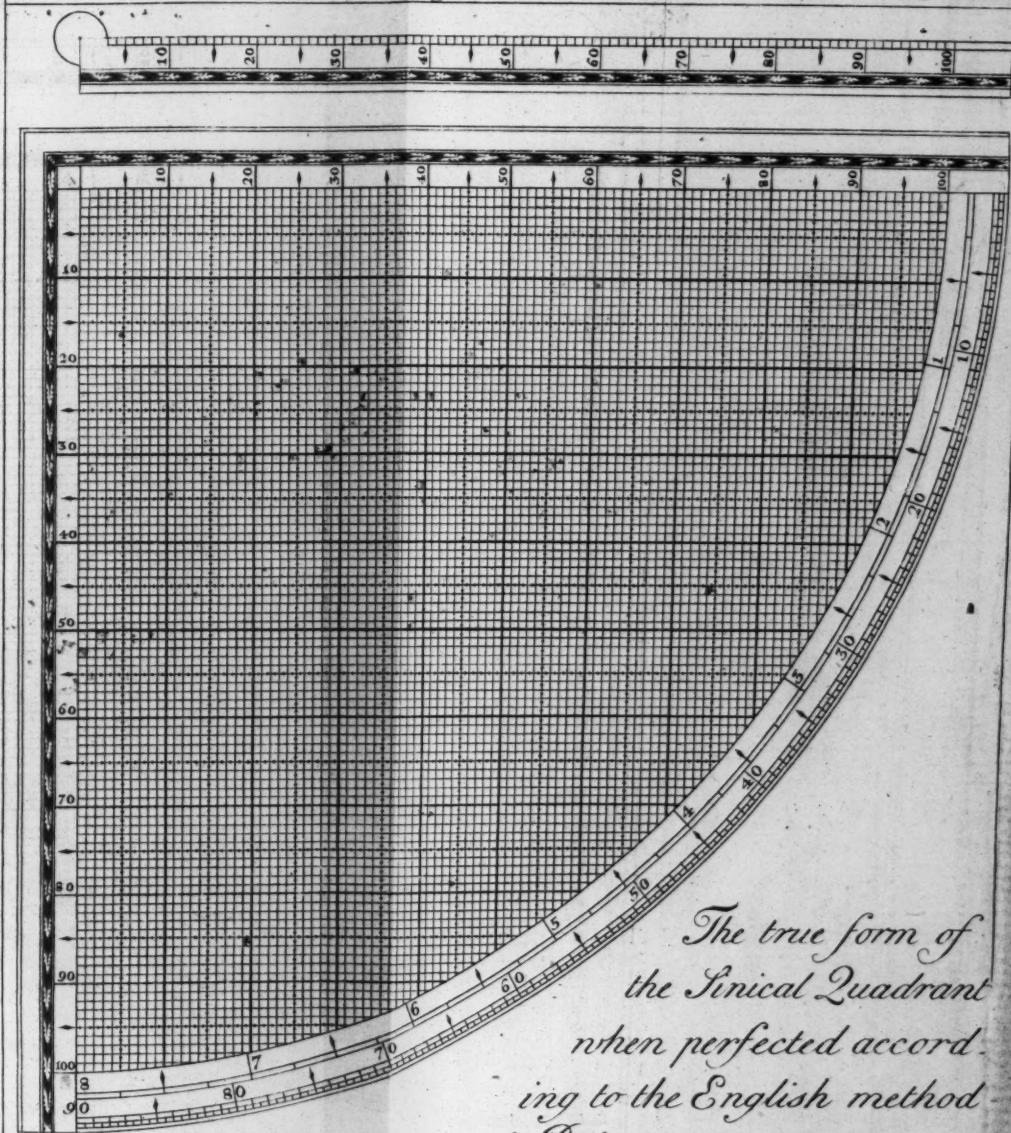
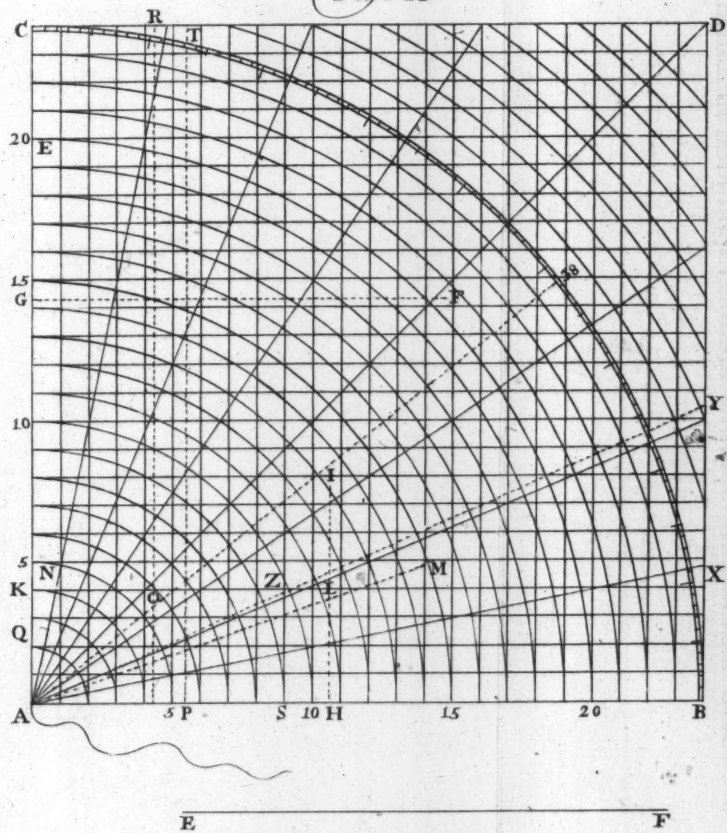


F. 25. Vide Plate 3.



68

Fig: 25



The true form of
the Sinical Quadrant
when perfected accord-
ing to the English method
of Projection



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OF THE
WORKING
OF A
SHIP.

ADVERTISEMENT.

THO' the working of a Vessel is, without dispute, the most important knowledge with regard to the sea-service, yet no one hitherto has writ a compleat treatise on the subject. F. Pardies, indeed, in his tract of local motion, has, in few words, given great light into this matter; nor would it be difficult, from the principles he has advanc'd, to deduce all that may be thought necessary on the subject. The Author of the Theory of working a ship, has entered into the matter more largely, and most ingeniously and solidly determined four or five of the most difficult propositions. The tract, call'd The exercise of working a ship, is also a very useful

useful work, and must be acknowledg'd a production suitable to that great capacity, which all France admires in its most illustrious Author. Nevertheless, these several works not seeming to me sufficient to give a perfect knowledge in this art, I have undertaken the following tract, wherein I have endeavour'd to explain in order, all the several movements of a Vessel, with the rules for their proper application. I have, in the clearest manner I was able, laid down all I thought proper for my design, believing I had more reason to fear censure, for omissions of any thing necessary to the instruction of those for whom I write, than for the publication of what might otherwise have been better concealed from Strangers.

Caution to the English Seaman.

To this advertisement of the Author's concerning the original, I beg leave to subjoin the following caution to the English Sailor, with respect to the translation: That he would not be prejudiced against the work, upon sometimes finding the French practice different from the English: For tho' the reasons why a thing is done, may not be affected by the manner in which it is performed; yet if according to the worst way of performance, the expediency of the thing be demonstrated; certainly the better method is thereby more abundantly justified. Therefore as the Theory here laid down will be found universal, and as the English are confessedly the best navigators in the world, its application to their practice will consequently appear the most natural; and will probably furnish many useful hints for future improvements.

Of



Of the Working of a Ship.

BY the working of a Ship, is here meant, the Art of giving a vessel all the motions of which she is capable, and the giving them properly.

We shall divide this Tract into three parts. In the first of which we shall consider the use and effect of several Instruments make use of to put a Ship in motion. In the second, the several ways of turning a Ship. And in the third, lay down rules for navigating a Vessel upon the open sea, from one Port to another.

DEFINITIONS.

1. The *Motion* of a body, is that which carries it successively, from one place to another.
2. The *Direction* of motion, is the right line along which the body is thrust, or determin'd to move, and through which it moves itself in effect when free. Thus when *Fig. 1.* the body A is determin'd to pass along the line A B, the line A B, is call'd *The direction of its motion.*
3. The *Wind* may be considered as a great number of little bodies of air thrust along in parallel lines. These lines compose what may be call'd a *Bed or Body of Wind*; so likewise a *Current* is a great number of drops of water,

pushed forward in parallel lines, which form the *Body of the Current*.

4. In each of these lines which form the body of wind, may be considered two points, of which the nearest to the rise of the wind, is said to be to windward of the other. For example, if the corpuscles which compose the body of

Fig. 2. wind are thrust from the points A, to the points B, we say the points A, and the points C, are to windward of the points B; and that the points B are to leeward of the points A and C. We say likewise, that all the points A, on the line A A, perpendicular to the body of wind, are equally to windward. The reason is, because if two vessels D and E, depart at the same time from two points of the line A A, and move with equal velocity along the lines E F and D F, equally inclined to the body of wind, they will meet each other at the point F, and neither shall pass to windward of the other.

5. Supposing again, the wind to blow from A to B, if a vessel made her course from B to A, it would be said she went in the wind's eye, or directly against the wind, which is impossible; so likewise, if a vessel sail along the line B G, she would go less to windward, or less against the wind, than in the line B A; but more to windward than in the line B H.

6. We say a vessel comes to the wind, or comes to, when she ranges on a line more contrary to the direction of the wind; and that she wares or falls off, when she ranges on a line less contrary to the wind. For example, if a vessel on the line B H,

BH, should range on the line BG, she comes too; but if being on the line BG she should range on the line BH, she wares.

7. When a vessel keeps a-line the most contrary to the wind that she can sail on, she is said to sail upon a wind; but when she runs upon a line nearly perpendicular to the course of the wind, we say she sails with a large wind; and having the wind right a stern, she then sails before the wind.

SUPPOSITIONS.

1. If at the same time that the body A, moves from A to B, in the canal *Fig. 3.* A B, the canal it self is carried from A B to C D, the body A shall move in the diagonal A D, and its true motion be compos'd of the motion carrying it from A to B, and of the motion whereby it is carried with the canal from A B to C D; that is to say, if the body A moves in the diagonal A D, two motions may always be distinguished, one approaching the line B D perpendicular to the canal A B, the other approaching the line C D, parallel to A B.

2. A body in motion will only thrust on such others as oppose it. Therefore the body A moving along the line A B, parallel *Fig. 4.* to the line C D of another body, will impress no motion on it; but moving *Fig. 5.* in the line A C, perpendicular to C D, it will then communicate all its motion. Farther, if the motion of the body A be along the diagonal A D, it will communicate in the point D, only the
E motion

motion approaching the line CD ; that is to say, it will make the same impresson as if it had fallen upon CD by the perpendicular AC , or BD , provided it took up the same time in running through BD , as it does in running through AD .

3. From whence it follows. 1. That when the body A falls upon CD , in the diagonal AD , its own motion is to that it communicates, in proportion as the sign total AD , is to AC , the sign of the angle of incidence ADC . 2. That the body A does not force the body CD , by the direction AD , but by a direction perpendicular to the face CD , viz. AC or BD .

R E M A R K.

The body CD thus thrust, does not *Fig. 6.* in effect move in the direction BD , perpendicular to the face CD , but under two considerations, 1. That all parts of the body CD receive the same impresson, all being struck in the same manner, or that the impresson made on the point D , which is suppos'd the center of gravity, be equally communicated to all the other parts. 2. That the several parts of the body CD have all the same facility of moving.

4. If an infinite number of cylinders *Fig. 7.* EF , fall perpendicularly upon the face AB of a body, they will have a greater effect than if they fell upon the two faces AC and BC ; because to the plane face AB , they would communicate all their own motion, but to the faces AC , BC , only a motion in proportion to their own, as the signs of the angles $EF C$, to the sign total: From whence it follows, that a
body

body A B will more easily divide the water in presenting its two faces A C, B C, or its convex face A B C, than in presenting its plane face A B. *

5. When the wind which strikes a sail, freshens, two things happen: 1. Each of those little bodies which compose the wind, push the sail with greater force. 2. A greater number of those little bodies strike the sail in an equal time. From whence it follows, that the motion which the wind impresses on the sail, increases in a duplicate proportion to its force, which is nothing else but the velocity of the bodies which compose it.

6. The difficulty which a ship finds in dividing the water, arises from that the water strikes the ship with the same force, as if she remained immoveable, and that the water came against her with the same velocity as she moves against the water. From whence it follows, that the difficulty of a ship's cutting the water, increases in a duplicate proportion to her velocity; for the faster she moves, 1. Each particle of water strikes against her with greater force: 2. A greater number of such particles strike against her in an equal space of time.

7. From which observations it follows, that the velocity of a ship increases only as the roots of the forces which give it motion.

* Of the Motion of Fluids, and the Resistance made to projected Bodies; Vide Sir *Is. Newton's Principia*, Book II. Sect. 7.

8. If the sail AB be perpendicularly opposed to the wind, and another equal sail

Fig. 8. CD be set slant-ways, the impulse on the sail AB will be greater than on the sail CD , in two respects ; for 1. The force of each particle of the wind upon the sail AB , in comparison with the same particles on the sail CD , is as the sign total GE , to the sign GH of the angle of incidence CEG (by *Sup.* 2). 2. The quantity of wind which strikes the sail AB , in comparison with the quantity of wind striking the sail CD , will also be as the sign total EA , to the sign FC , of the angle of incidence CEF . From whence it follows, that the impulse upon the sail AB , will be to that upon the sail CD , in a duplicate proportion of the sign total, to the sign of the angle of incidence $GE C$, and universally the impulses which a sail receives from the same wind in different situations, are to one another as the squares of the signs of the angles of incidence, which the wind makes upon the sail.





PART I.

*Of the INSTRUMENTS made use of to put a
Ship in Motion.*

PROP. I.

Of the Hull or Body of a Ship.

THE whole figure of a vessel may be referred to two profiles, *viz.* the vertical A, and the horizontal B. *Fig. 9.*

1. The profile A, shews that a vessel naturally presents her head to the wind, and the profile B, shews that she as naturally presents her head to the current; for in that position only, the wind or current have the least hold of her, and striking equally on each side, keep her as it were in a perfect equilibrium.

2. It does not hence follow, that if the hull of a ship were floating at liberty in the middle of the sea, that it must needs always present its head to the wind; because in proportion as the ship gets stern-way, the water abaft getting more power of her stern, forces it up against the wind; but the wind in its turn, as it thereby obtains a greater

E 3

hold,

hold, repels it back again ; the ship therefore cannot keep one constant situation ; but must sometimes offer her head, sometimes her stern ; but most commonly her side to the wind.

3. 'Tis not the same in a current ; for if the vessel be therein free, she will constantly present her head to the stream, for the reasons before given ; because the water abaft, being carried on as fast as the ship, does not consequently strike against her counter.

4. If a ship could be so fix'd in the sea, as to turn easily about her center of gravity, she would constantly present her head to the wind, or the current.

5. So likewise, if a ship without wind or current, was mov'd by a power applied to its center of gravity, which would admit its turning any way, she would go head foremost, because the water, which is supposed motionless, would have the same effect upon a vessel in motion, as a current would have upon a vessel not in motion.

C O R O L L A R I E S.

1. From these considerations, we see why ships so easily come to the wind, and why it is necessary to increase the head sails, to make them ware.

2. The reason is as clearly seen, of a ship's falling off as soon as she gets stern-way, and why so long in staying when she runs a head ; for when she goes forward, the water striking on both sides, hinders her from readily turning either to the right or left ; whereas in her recoiling or stern way, the water
abaft

abaft thrusting up her stern, causes her to fall off, as soon as ever she loses her perfect equilibrium.

6. If a ship were perfectly round, she would always keep the direction of motion given her; but being of a figure more adapted to cut the water with her stem, than with her sides, she does not always follow that direction of motion; for example, Suppose the vessel A B, forc'd along by the sail C D, whose direction is E F; if the vessel were round, she would keep the direction given, and sail on the line E F, and consequently the motion she would receive from the sail in this disposition, is a compound of two motions, one carrying her strait forward, the other side-ways. Or if the ship had the same difficulty to divide the water with her stem, as with her side, she would keep the line E F; that is, she would gain the length E A, right forwards in the same time, that she would gain A F side-ways. But if a ship finds ten times the difficulty to divide the water with her side, as she finds in dividing it with her stem, she will then gain but the $\frac{1}{10}$ of A F, viz. A G, in the time of her gaining the length E A; and consequently she will be found at the point G, at the same time she would have been at the point F, if it had been as easy for her to have divided the water with her side as with her stem.

R E M A R K S.

1. The line E G will be the true course of the vessel, and the angle A E G the angle of variation. The line A G will always be to the line A F, as the difficulty the ship finds in dividing the water

by her head, is to that she finds in dividing it by her side.

2. The angle AEG , changes, and becomes greater, in proportion as the angle AEF is increased; for the tangent of the angle AEG is to the tangent of the angle AEF , as AG to AF .

7. If any obstacle absolutely takes off the side motion of a vessel, she will keep the line EA , and will arrive at the point A . in the same time she would have come to the point F , if she could as easily have cut the water with her side as with her stem.

C O R O L L A R Y.

From hence it follows, that if a vessel did not fall off, and a semi-circle were made *Fig. II.* upon the line of direction EF of the sail, the vessel would arrive in the same time at any intended point of the semi-circle; that is, she would come in the same time to the point H , or the point I , as to the point F , if she had no more difficulty in dividing the water by her side than by her stem.

8. As all vessels do not fall off alike, it is necessary to find the lee-way of any particular vessel; which may be thus *Fig. 10.* done. Suppose the ship AB advancing towards some coast; take notice of some remarkable point, as H on the shore towards which she is advancing, which you may observe two ways.
1. Set the point H by the compass from time to time,

time, and if you find it always in the same rumb, 'tis an infallible mark, that the ship sails on the line E H. 2. If the point H answers to some other point as I, and continues to do so after the ship has sail'd some time, it is evident the ship keeps her course E H I. When by one of these methods you find the ship keeps the line E G H, you may compare the angle A E G, with the angle A E F, by the following analogy ;

The tangent A G of the angle A E G : the tangent A F of the angle A E F :: the difficulty the ship finds in dividing the water by its stem : the difficulty of dividing the water by its side.

R E M A R K S.

1. As the waves and currents render this experiment very uncertain, it must be frequently repeated, and that under different circumstances.

2. The hull of a ship is also in some measure to be considered as a sail, giving the ship a direction perpendicular to that of her keel ; this direction with that of her sails, compose a mean direction between E F, and E L, and with this mean direction the lee-way should be computed : But as the thing is indeed impracticable, 'tis sufficient to make the experiment as before directed, with the sail set in different positions ; when if the same ratio is constantly found between A G and A F, it may be concluded that the ship's hull makes no difference in the trial ; but if the ratio of A G to A F, is found least when the sail is sharpest trim'd, the difference is justly attributed to the ship's hull ; and the remedy is to brace the sail in proportion to such difference.

9. If a ship A B, were of the same figure, both head and stern, we might from thence draw the following conclusions. 1. That if her

Fig. 12. head A only, were push'd in a direction perpendicular to her keel, she would turn about, and the center of her motion would be evidently in her stern B; so likewise if she were push'd by the stern, she would turn about her head A.

2. If she be push'd at the same time on the same side, and with equal force in the points A and B, her movement will be in a line perpendicular to her keel. 3. But if she be push'd on different sides at the same time, she will then turn about her center of gravity.

10. The form of a ship gives her a greater facility of dividing the water with her head than with her stern: If the vessel *Fig. 13.* A B be push'd by the stern B, with a direction perpendicular to her keel, she will not turn about her head A, but about her center of gravity; whereas, if she be push'd a head with a direction perpendicular to her keel, she will turn about her stern B, unless at the same time she be push'd on the contrary side a stern, for then she will turn about her center of gravity. From whence it follows, that when a ship turns, she almost always turns about her center of gravity; because she is almost always thrust fore and aft on opposite sides. These rules are so plain they need no farther explication.

P R O P. II.

Of the Rudder.

1. Suppose AB the keel of a ship, and BC the rudder inclined upon that keel; as the keel moves forwards, the water will have the same effect upon the rudder, as if the keel remain'd immoveable, and the water run a stern in lines parallel to the keel, with the same velocity as the keel advances; that is, the water will strike the rudder by lines sensibly parallel to the keel, and push it back with a force proportionate to the velocity of the keel. *Fig. 14.*

2. All the parts of the rudder being struck with the same force, it will be repell'd in the same manner as if the whole force which strikes it were united in its center of gravity D . Draw the perpendiculars DF upon the keel continued, and DG upon the rudder; if then the absolute force of the water be measured by the line BD , the impression it makes on the rudder shall be measured by DF the sign of the angle of incidence BDE , and the impression of the rudder on the keel by FB the sign of the angle of incidence BGD (by *Sup. 2.*) But since the impression of the water on the rudder increases in a duplicate ratio of the sign of the angle of incidence (by *Sup. 8.*) it may be concluded, that the force of the rudder upon the keel may be express'd by the product of the sign BF , multiplied by the square of the sign DF . Thus by a trigonometrical calculation may be found, the force of the rudder upon the keel in every position; and it will appear, that the most advantageous situa-

tion of the rudder, is when it makes the angle C B G with the keel continued of $54^{\circ} 44'$. For if the said angle be made either more or less, the force of the rudder upon the keel will be diminished. *

R E M A R K S.

1. Care should be taken that the helm be never so far put over, as to make the angle C B G of the rudder with the keel more than $54^{\circ} 44'$.

2. Though the more the rudder be inclin'd, the more it stops the ship's way, it does not therefore follow, that the foregoing proposition is the less exact, as the Author of the Theory seems to apprehend; since the impulse of the rudder is given before the ship's way is lost, and her after-motion, is according to the first stroke of the water against the rudder.

3. Another remark of the same Author's is better founded, for it is true, that a ship's not always advancing in a line parallel to her keel, does something affect the said rule; for the oblique

* The Author here gives an algebraical calculation of the most advantageous angle the rudder can make with the ship's keel; as likewise he does at the end of the 18th Prop. of the most advantageous situation of the sail with the wind; but as he has inserted no Tract upon the subject of Algebra in his collection, but seems to have purposely omitted it throughout his whole Scheme, I rather chuse to leave out the said calculations, than improperly (I think) introduce them into a Work, which the Author himself, in the projection of his Plan, seems to have thought compleat without Algebra.

lique way of a ship requires that the angle of inclination of the rudder with the keel prolong'd, be greater when the rudder is to leeward, and less when to windward.

4. When the rudder B C is to leeward, it pushes the after part of the keel to windward, and makes the head of the vessel fall to leeward; on the contrary, if the rudder is to windward, it thrusts the after part of the keel to leeward, and makes the vessel come to the wind.

5. This is to be understood when the ship has head-way; but if she goes a stern, the effect of the rudder is quite different, for the water which is behind her strikes it in the direction H D; so that in stern way, if the rudder be to leeward, it brings her head to the wind; if to windward, the contrary.

P R O P. III.

Of the Sails in general.

1. Sails have the more force the higher they are hoisted; not because the mast is a kind of Lever, as some of the ancients thought; for it is very certain their height does not increase their proper motion in that respect: But the greater force they obtain in that situation is occasioned by the winds blowing more fresh aloft, where its motion is less impeded by the vapours of the earth or sea; besides that the higher the sails are hoisted, they are the more exposed to the wind.

2. Sails have more force the tauter they are hoisted, because, 1. They catch more wind. 2. The
wind

wind strikes them more directly. 3. The impression they receive is more uniform. For supposing the taught sail A B, and the concave one A C B; 1. The taught sail A B, shall take as much wind, as the concave one A C B, though it be larger. 2. The wind communicates all its motion to the taught sail, as it falls perpendicularly upon all its parts; but to the concave sail, only a motion in proportion to the angles of incidence (by *Sup. 2.*) If the wind does not fall perpendicularly upon the sail, but strikes it obliquely by the lines A D, C D, B D, the wind will hardly have any effect on the windward part of the concave sail, and its impulse upon the leeward part, to which it is more perpendicular, serves scarcely for any thing else but to flat off the vessel, because it is nearly parallel to her keel; nay, it often happens, that that part of the sail near the clue, when the sheet is haled aft, proves intirely a back sail, and is of great disadvantage.

3. These considerations shew how much they are deceived, who cut their sails so as to bag in the middle, imagining that such bagging gives the wind a greater power, especially when sailing close upon a wind; whereas, indeed, the part so bagging out is hardly struck at all by the wind, and is only fill'd wth eddies from the adjoining parts of the sail, which have no force at all.

4. For the same reasons the top sails have a greater effect upon a wind than the lower sails; for the lower sails not having yards to spread them at the foot, do not oppose the wind so flat. However in sailing close upon a wind, the lower sails are not to be brac'd with the foot without board, because

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because then not having a sufficient power to trim them taught, they will become in a manner useless; they are best spread by belaying the tacks and sheets to cleats, fastned to the ship's side, in such manner that they may be brac'd by the yards above, as the top sails are by the yards below. *

5. So likewise those top sails, whose lower yards are too long, are not so fit for sailing close upon a wind, because they cannot be hal'd sufficiently taught. It is likewise proper the main sail should be so cut, that the parts nearest the clue may not bagg when the ship is close upon a wind, because the direction of those parts would rather hinder her way.

6. When the wind *E C* is perpendicular to the sail *A B*, and the sail *Fig. 16.* *A B* perpendicular to the keel *C D*, the sail *A B* is thrust with the whole force of the wind, and communicates its whole motion to the keel, moving it a head in the direction *C D*; so that this Disposition of the sail with the wind, and with the keel, is the most advantageous for making head-way with only one sail: But in ships which

* When a ship is to keep close upon a wind, the *English* manner of trimming the sails is as follows: The main-tack, fore-tack, and mizen-tack are brought close by the board, and over-hal'd as forward as may be; the bowlines are the same on the weather-side; the lee-sheets are hal'd close aft, but the lee-sheet of the fore-sail not so close as the others, unless the ship gripes; the lee-braces of all the yards are braced aft; and the top-sails are braced, and govern'd as the sails to which they belong.

which have many sails in this disposition, those a stern will keep the wind from filling those a head, therefore ships make most way when the wind is just abaft the beam; at least if there does not run too great a sea. And some Corsairs in chasing a vessel which sails before the wind, allow themselves two points of the compass sometimes on the starboard, and sometimes on the larboard side, in order to come up with her the sooner. It is not altogether the same thing when the sea runs high, for the waves striking upon the ship's counter, supply the deficiency of the wind on the head sails, and would make the ship fall very much off, if she were not exactly in the direction of the wind.

7. When the sail A B inclines with the wind, the impulse it receives therefrom, decreases in a duplicate proportion of the sign of the angle of incidence (by *Sup. 8.*) and when the sail A B, inclines with the keel C D, it will communicate thereto all its own impulse; but since its direction is not right a head, the head motion it will impress thereon, will decrease as the sign C D of its inclination with the keel.

8. Square sails have a greater power than triangular ones, as being larger; but then they require more rigging, are more difficult, and slow in handing, besides that they are more dangerous. From whence comes that diversity of sails made use of in different vessels.

9. The most advantageous situation of a triangular sail is, when the yard stands before the
5 mast;

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maſt; becauſe were it behind, 1. It would cauſe two baggings on the two ſides of the maſt, which would render a great part of the ſails uſeleſs. 2. The yard would bear harder upon the maſt, and make it more in danger of breaking. 3. The wind would have power of the ſail before it is brac'd which would put the veſſel in danger of overſetting, if the wind ſhould take it when it is in a poſition parallel to the keel. *

P R O P. IV.

Of the Head Sails.

1. The head ſails ſerve to keep the
 Fig. 18. veſſel ſteady, hindring her from ſheering to and again; for ſuppoſe A B the veſſel, if ſhe be only impell'd by her main maſt C D, her fore-part B will indifferently receive every motion of the bodies it meets; for ſince the motion of the point C tends precifely only to the carrying the point C forwards, it will only have its full effect upon the point B, when the ſaid point B is precifely right before the point D, and conſequently will not hinder the point B from receiving from the waves, a motion carrying it either to the right or left. But if the point B is fix'd to a power, which will carry it right forward, it

* Our ſhips have but one triangular ſail bent to a yard, viz. the mizen, which is ſhifted to leeward of the maſt every time the ſhip tacks, and can therefore be of no ill conſequence. But there are certain ſmall veſſels much uſed in the *Mediterranean*, which have only triangular ſails, as likewiſe have their gallies; but ſtill in going about, they are always ſhifted to leeward of the maſt.

it will draw after it the rest of the vessel, and the water which strikes against both its sides, will keep the ship in equilibrium, and so overcome the motion which the waves would impress on the point B, which would otherwise throw her off to the right or left, and to this purpose the head sails chiefly serve.

2. The head sails, when brac'd sharp to the wind, help a ship to ware. For let the
Fig. 19. sail A B inclined upon the end of the keel, receive the wind F D from abaft, it will impress on the point D, a motion whose direction will be D E (by *Sup. 2.*) and which will consequently be composed of two motions, the one carrying the point D right forward, and will be express'd by the sign D H, of the angle of the sail with the keel; and the other carrying the point D sideways, and thrusting it to leeward, with a force expressible by H E, the sign of H D E, the complement of the angle of the sail with the keel.

3. From whence it follows. that the more the head sails are braced, the sooner the vessel wares, as having more force to flat her off; for in bracing the yard A of the sail A B, 1. The angle of the wind upon the sail is increased, *viz.* F D B, and consequently the motion the sail receives from the wind (by *Sup. 8.*) 2. The angle E D H is increased, and consequently the force of the sail to thrust the point D to leeward (by the prec.) This rule is commonly found true in practice. Nevertheless the wind F D may so come from abaft, that in bracing in the lee-brace, the angle of the sail with the wind, may be so diminished, that the sail

fail may lose more of the force it receives from the wind by the diminution of the angle $F D A$ than it acquires by the augmentation of the angle $H D E$, to make her ware. But this can only happen to such sails as may be so brac'd as to become nearly parallel with the keel.

4. If the wind $D F$ take the fail $A B$ aback, the vessel will either fall *Fig. 20.* off, or come to, according as the lines $F D$ divide the angle of the fail with the keel; that is, if the line $F D$ divide the obtuse angle of the fail with the keel, she will fall off; but if the line $F D$ divide the acute angle of the fail with the keel, she will come to; in both cases the sign $E H$, of the complement of the angle $B D H$, measures the force of the fail, either to flat her off, or bring her to.

5. In the first of these two cases, it commonly happens, that the more the fail is inclined with the keel, the more the angle of the wind with the fail is augmented; and consequently the more the fail is inclined, the more force it has to make the ship fall off. But it is not the same in the second case; for if the yard be too much brac'd in, the angle $F D B$ of the wind with the fail will be diminished, and may become so acute, that the wind shall hardly have any force upon the fail. It is therefore necessary, that the angle $F D B$ be always greater than the angle $E D H$, since the force of the wind upon the fail increases in a duplicate ratio of the signs of the angles $F D B$; whereas the force of the fail to bring the ship to the wind, increases only in proportion as the signs of the angles $E D H$. In short, it is easy to determine

mine in all cases, the content of the angle FDB which shall have most power to bring a ship to the wind; since the product of the square of the sign of the angle FDB , by the sign of the angle HDE , expresses the force of the sail in bringing a ship to the wind, and consequently the angle FDB will be most advantageous, when it makes that product greatest. A table might easily be calculated for this purpose, if it be found useful in practice.

6. What has been said of the head sails, may be applied to the sprit-sail, which is still more useful in flattening off, or wareing a ship, as it is farther removed from the ship's center of gravity, and is capable of being braced sharper, as not being hindered by the shrouds: Its chief use being to keep the ship from sheering backwards and forwards; for being very much inclined a head, it greatly checks the rising motion which the waves impress upon the head of the ship.

7. The fore sail, and fore-top sails being situated upon the end of the keel, have all the effects of the head sails. 1. They hang something forward, to prevent the vessels sheering. 2. The fore sail is narrowest at the bottom, that it may more easily be braced taught. 3. The fore sail and fore-top sails have but little force (the ship wareing) when their lee-braces are hal'd in close, because then the angle they make with the wind is very small, though that which they make with the keel is large enough. 4. For which reason when they would ware expeditiously, they hale in the weather braces as close as possible, which makes the ship immediately fall off; for so they call this way of wareing, by lay-

ing the head sails aback. 5. The fore sail serves likewise to turn to windward, after the manner explain'd above. 6. The fore sail and fore-top sails may also, if laid aback, bring up the ship to the wind, notwithstanding they stand perpendicular to the keel. For let *AB* *Fig. 21.* represent a sail perpendicular to the keel *CD*, and the course of the wind be *CE*, the sail being thrust by the wind *CE*, will force the vessel back by the direction *CD*, (*Sup. 3.*) but as at the same time the wind will find better hold on the stern, it will consequently push it to leeward, and make the ship lose its equilibrium, the water too abaft, having better hold on the windward side of the ship's counter, and pushing it likewise to leeward, the vessel will be in danger of turning quite round; to hinder which effect of the fore sail, they put the helm a-lee, that so the water a stern pushing the rudder *DF* to windward, may resist the wind which thrusts the stern *D* to leeward.

P R O P. V.

Of the Main Sail.

1. The motion impress'd by the Main Sail on ship, tends directly only to move that part of the vessel where the main mast is fix'd, *viz*, its center of gravity, communicating to the other parts no more force than is necessary to move on the said center of gravity in the direction of the sail

2. If the main sail *AB* is thrust forward in the direction *CD* parallel *Fig. 22.* to the keel, it shall impel the ship in the same direction, and the water striking against both

both sides, shall keep her in equilibrium, and hinder her turning either to the right or left.

3. If the direction C D of the main
Fig. 23. sail were perpendicular to the keel A B, the ship would by degrees range herself in that direction, and would bring her head A to the point D, for the water finding better hold on her stern B, than on her head A, will by degrees repel it behind the point C.

4. If the direction of the main sail
Fig. 24. is oblique upon the keel, as C E ; the ship will sail in another direction between C D and C E, and make more head than side-way ; because the water striking against her sides, will keep her in equilibrium, and this oblique direction of the sail will commonly hinder her turning either to the right or left. But still this doth not hinder but that a ship only under a main sail, may readily enough come to the wind ; for the wind having great hold of the stern, will force her after-part to leeward, even with more force than is necessary to break the equilibrium.

5. When the wind takes the main
Fig. 25. sail A B aback, in the line E C, the vessel is thrust in the direction C F, and the same thing will happen, as when the fore sail is in the situation above explain'd.

6. If the main sail A B being taken with the wind aback in the line C E, is not perpendicular to the keel, but that its direction is some other line as C H, the ship will nearly keep the same direction ; but the water thrusting up her stern against

against the wind, will soon make her fall off, unless the rudder *F G* being put to leeward, overcomes the said force of the water upon her stern. *Fig. 26.*

P R O P. VI.

Of the Mizzen.

1. The Mizzen serves as the other fails, to give the ship head-way ; but its chief use is to bring the ship's head to the wind, by forcing her stern to leeward.

2. The triangular figure of the mizen is well adapted to this design ; 1. Because it is easily hal'd up or out. 2. It presents itself more effectually to the wind, as its yard is less flexible than a rope or stay. 3. The shrouds are no hindrance to it, but it may be easily inclined in any manner with the keel, inasmuch that it may be full when all the other fails are aback.

3. It is true, that triangular fails design'd to give ships head-way, ought not to have the sheet hal'd to windward, lest the greatest part of the sail should become a back sail. But it is not so with the mizen, whose chief use, as was said, is to force the after-part of the ship to leeward, by a line perpendicular to the keel ; for it has oftentimes more force to bring a ship to the wind with the sheet to windward, than to leeward, as when the wind is far forward. For let *A B* represent *Fig. 27.* the ship, and *H G* the wind, then shall the mizen *CD* have more force to bring the ship to the wind, than the mizen *FE*. However the making thus a back sail of the mizen, is seldom practised,

sed, except in some extraordinary cases, because it breaks the ship's head-way.

PROP. VII.

Of the other Sails.

The other sails which are made use of besides these already explain'd, as bonnets and stay-sails, have nothing particular. It is only necessary to observe, that oftentimes the stay-sails only serve to make a ship fall off, because they are parallel to the keel, as when a ship sails close upon a wind.



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P A R T II.

To turn a SHIP any way.

P R O P. VIII.

To render a Ship ready to turn easily any way.

1. **T**HE figure of a ship causing her naturally to present her head to the wind, makes it necessary to have a great proportion of sail forward, for the more readily wareing her.

2. Notwithstanding which, there are many vessels too ready to come to the wind, and unapt to ware; which fault may proceed from several different causes: 1. Some have their sterns too high built, and their poops serve as a sail abaft. 2. Others have their fore-mast set too far aft, which makes them less capable to resist the force which so readily carries them to windward. 3. Others are built too sharp a head, which is remedied by thickning the bows.

3. If a ship be too backward in coming to the wind, the fault is to be corrected by some opposite means.

4. Great care ought to be taken, that the rudder be well proportion'd to the ship, and that it be sufficiently expos'd to the water that passes along the sides of the vessel.

5. When a ship is in a just equilibrium, and feels her helm as she ought, it is still no easy matter to keep her constant in her course, because of the uncertainty of the waves and wind ; it is therefore necessary to take the following precautions, 1. The range of the ship from her course, ought in the very beginning to be broke, which a light motion of the helm will then easily do. 2. When a ship is much yaw'd from her course, you must not bring her to it again at once, lest you throw her into a contrary sheer. 3. But if you should be oblig'd so to do, you must ease the helm before she be return'd to her course, to prevent the opposite sheer, which else the force of her way will be apt to run her into.

P R O P. IX.

To make a Ship fall off.

Let the vessel be A B, the head-sails D C, those of the main mast E F, the mizen G H, the line of the wind A N, I N, M N, the rudder B R, the tiller B O. Fig. 28.

1. A vessel is said to ware, or fall off, when her head is thrust to leeward, or her stern to the wind (*Def. 6.*)

2. When a vessel has head-way, the tiller is to be put over to windward, that the rudder B R may present itself to the current of water to leeward, and so push up the point B to the wind, which

which cannot be done without making the head A fall off to leeward (*Prop. 1.*)

3. To ware the easier, hale up the mizen, that so the line of the wind N M, which thrusts the stern to leeward, may not impede the impulse of the rudder B R, in bringing up the stern to the wind.

4. Encrease the head-fails, and brace them in as sharp as possible to leeward, that they may have the more force to make the ship fall off. (*Prop. 4.*)

5. Hale up the main fail, and shiver the main-top fail, in order to ease the ship's way, which will facilitate her turning; but take heed you lay not the main-top fail aback, which would perhaps give her stern-way, and so bring her again to the wind, especially as the rudder B R is to leeward.

6. Another way to ware a ship, is to brace in the head-fails as much as possible, to windward, that the wind A N may have the greater power, and that their direction being less inclined upon the keel, they may have more force to thrust the point A to leeward, and so make the vessel fall off. But this method is not practised without an absolute necessity, because it very much hinders a ship's way; and when other ships are in company, puts her in danger of falling foul of those which follow. *Fig. 29.*

7. When this practice is made use of to avoid a danger, the main fail and mizen-top fail may be laid aback, in order to give the ship stern-way, and the helm should be put over to leeward, that it may

may not check her falling off. But skilful mariners take care not to shift the helm, before the ship begins to get stern-way.

P R O P. X.

To bring a Ship to the Wind.

Fig. 30. To bring the Ship A B to the wind, that is, to turn her head to windward, the following things are to be done.

1. Put over the tiller B O to leeward, that so the rudder B R meeting the current of water to windward, may force the stern B to leeward, which will consequently bring the head A to the wind (*Prop. 1.*)

2. Hale out the mizen G H, that the wind N M may force the stern M to leeward.

3. Diminish the head sails by letting go the fore sheet, and setting in the weather braces.

4. Make what sail you can on the main mast, that the ship having more way, may the better answer her helm; and that the wind may have more force upon the mizen, and after-part of the ship. To explain myself.

The swifter the ship's motion is, 1. The water strikes the stronger against the rudder. 2. It pushes the stern of the ship with more force. 3 The wind has a greater effect upon the mizen, and after-part of the vessel, therefore the swiftness of a ship's motion helps the rudder every way in bringing her to the wind. But in falling off, as it helps on one hand, in striking stronger against the rudder;
so

so it hinders on the other hand, by its force on the mizen, and stern of the ship, in pushing her after-part to leeward.

PROP. XI.

To Tack with the Wind before the Beam.

To Tack, is to turn a ship that is close hal'd on one side, so that she may be the same on the other. To tack therefore with the wind before the beam, is to turn a ship so that she may still take the wind before.

Let therefore A B represent a ship, which is to tack, 1. After having given her as much way as possible, right the helm, and hale out the mizen; then when the vessel begins to come to, put over the helm B O to leeward, and brace to the fore-top sail, that the windward part of the sail may lay aback, which as before remark'd (*Prop. 4. 3.*) will help her to come to the wind. * Fig. 30.

2. Ease a little the fore-bowlines to windward, and the fore-sheets to leeward, that so the head sails may lose all power of making the ship fall off. Fig. 31.

3. The mizen may likewise be brac'd to leeward, that the wind N M may have the more force

* The *English* practice in tacking is, as soon as the helm's a lee, to let go the fore sheet, and not lay the fore-top sail a-back, till the ship is so far come up as to shake it; then laying it a-back, they tend it, and trim their after sails sharp, not easing their fore-bowlines till they find the ship falls off too fast.

to bring her to ; but this is not done but in case of necessity, because it deadens her way.

4. The head-fails are not to be shifted, till the ship has pass'd some degrees beyond the line of the wind, lest the wind N A should
Fig. 32. force back her head A, and hinder her coming to.

5. For the same reason it is, that the bowlines and sheets of the fore fails, are not entirely let go, lest the fails should bag behind the mast, and so force the ship's head to leeward.

6. When the ship is come enough about to shift the fails ; the mizen should be
Fig. 33. first set, that so the wind N M may break the way she has in turning.

7. In filling the fails again, begin with the after-ones, if they cannot be all filled together ; in order to make the most of the time in which the ship is falling off, to fill the head-fails. In this case the main fail, as soon as it shivers, should be immediately shifted. *

8. There is no fear that the wind A N, should make the ship fall off too much, since the braces D being eas'd, and the main fail being set, will bring her up again to the wind.

* Our way is always to brace about our after-fails, and keep the head fails a-back till the after-fails are full, and then brace about the head fails ; for a ship in tacking is frequently caught, or comes back again, if the head-fails are brac'd too soon.

9. 'Tis not easy to tack a ship, only with her top sails, when the sea runs high, because they do not give a ship way enough to overcome the swell which beats on her bow; the courses are yet less sufficient, as giving her still less way, besides that the fore sail when it takes aback, makes too much of a bag to windward of the mast, which will flat her off again.

10. If when a ship begins to come to the wind, her head-sails are brac'd to, though not exactly perpendicular to her keel, she will stay sooner, but will fall more a stern: On the contrary, if they are not brac'd, the ship will gain a head in staying, because the force of her way will sustain her against any contray impulse impress'd on her by those sails aback; therefore when a ship is lively enough to stay, the head-sails are not brac'd to at all.

P R O P. XII.

To change the Board with the Wind abaft the Beam.

Suppose the vessel A B, were obliged to change her board with the wind *Fig. 34.* abaft the beam, either because she cannot bring the wind forward, or that for some particular reason she is obliged to change her board with the wind abaft the beam, and to take luff for luff.

1. Hale up the mizen, and put over the tiller O B to windward, then when the vessel has got lee-way, bring to the weather braces, and in proportion as she falls off, continue to brace in, that

so when the ship comes right into the direction of the wind, the sails may stand trim'd right before it.

2. When the ship's way has brought her beyond the line of the wind, hale out the mizen, that so with the rudder, which will then stand right for bringing her to the wind, it may continue to help the vessel to turn; continue likewise to brace in the sails, till they are brought close upon the wind. Then haling up again the mizen, shift the helm to break the force of her way to windward.

3. If when the mizen is hal'd up, and the helm shifted, she does not fall off; it may be effected by bracing in the sails as close as possible to windward. But as soon as ever the ship begins to get leeway, right the sails again to help her, lest when she comes near the line of the wind, the
Fig. 35. wind N A should break the ship's way in turning.

4. Take care not to be too hasty in bracing the sails, when the ship begins to fall off, lest by some sudden motion the wind should take the sails aback.

P R O P. XIII.

To prevent the Accident, call'd building a Chapel.

A Ship is said to build a Chapel, when the wind, taking her a head, forces her unexpectedly about. This accident is dangerous, because it may throw a ship in the way of another a stern of her, or upon other dangers.

I. Suppose

1. Suppose the ship A B, take the wind a-head, if she remains in that disposition, the wind N A falling upon the sail C D, will make the ship come to the wind till she passes the line of the wind, when striking her with still greater force, it will bring her stern to windward. To hinder which, put the helm over to windward, hale up the mizen, and brace the head-sails D C to the wind, till the angle C A B becomes a little acute; that so the wind N A falling upon the sail D C, may thrust back the head A to leeward, and make the vessel fall off. Then when the ship has got lee-way, right the sails D C again, and hale out the mizen, putting over the helm too to leeward, to prevent her falling off too much. *Fig. 36.*

2. If the angle C A B be made very acute, the ship will fall off sooner, and force her less a-stern. But then it may happen, that the ship has already turn'd so far that the sails D C may shiver, or even fill, which will render it impossible to prevent the accident. 'Tis therefore proper to brace the sails C D no more than is just necessary to flat the ship off.

3. Suppose the ship A B has all its sails a-back, in order to fall a-stern, if after she has lost her head-way, the helm B O be put over to leeward, the water which strikes against the rudder when the ship begins to get stern-way, will throw up her stern B to the wind, and the wind N A will fling her head to leeward with so much force, that nothing can stop her turning about. But this accident may easily be prevented, by bracing a little the sails D C to the wind, that is, by making the angle C A B a little acute, *Fig. 37.*

and putting the helm and mizen to bring her to the wind. Nor need it be feared that the vessel should come too much to the wind; for the sails *C D* will receive the wind *N A* more perpendicularly, as the ship gains to windward, and force her with the greater strength to leeward.

4. Many skilful seamen make use of this practice when they sound, because the ship then makes little or no way, and is not at all liable to build a chapel.

P R O P. XIV.

To lye to under the Top-sails.

A ship is said to lye to, when her sails are so disposed, that producing contrary effects the one to the other, they render the ship as it were immoveable.

1. Let *A B* represent a ship, whose *Fig. 38.* sails are so disposed, that the angles *C A B*, *F A B*, may be somewhat acute, the mizen *G H* being hal'd out, and the rudder *B R* to leeward. In this situation, the head-sails will push the ship's head *A*, by the line *N A*, to leeward; and the after-sails *G H*, bearing her stern to leeward, by the line *N M*, will force up her head to windward: So likewise the sails *D C*, *E F* thrusting the ship a-stern, and the sails *H G* bearing up a little a-head, consequently as the ship cannot easily divide the water a-stern, she will remain almost immoveable, making but very little way, and that a-stern; for which reason the effect of the rudder *B R* will be to bring up the ship a little to the wind.

2. The

2. The lower fails being furl'd, and the top-fails a little lower'd, brace in *Fig. 39.* the fore-top fail DC, till the angle CAB becomes a little acute, gaining a little at the same time to windward, that the fore-top fail may be taken aback, whilst the main-top fail is fill'd by bracing it in to leeward. In this situation the ship is thrust a-head, and to windward by the main-top fail, (*Prop. 5. 4.*) and a-stern, and to leeward by the fore-top fail (*Prop. 4. 2.*) so that between both, she remains as it were immoveable.

3. If in this disposition the ship falls off too much, hale out the mizen, or make use of the mizen-top fail, and if notwithstanding all that, she still falls off, make the angle C A B less acute, and the angle C A N more acute, by bracing in the fore-top fail a little to leeward. There is no fear of her coming too much to the wind, because as she comes to windward, the fail DC will take the wind more directly, which will give it more power to flat her off. Thus a ship lies to most safely under a mizen; but then she is most liable to fall off.

4. The helm ought for the most part to be put over to leeward, since the vessel more commonly falls a-stern than gains a-head; for both the hull and rigging serve as a back fail.

5. A ship may lye to, with her fore-top fail DC fill'd, and her main-top fail EF a-back; and in this disposition she will not so easily fall off, because the fail DC keeps her closer to the wind, and has less force to flat her off. (*Prop. 4. 3.*) 2. The fail EF has more power to bring her to the wind (*Prop. 5. 5.*) There-

Therefore this way of lying to, seems the most convenient for a fleet in a line of battle ; but as it puts a ship in greater danger of taking the wind a-head, it is seldom used but in engagements, when it is of much more consequence not to fall to leeward, than to prevent the accident of taking the wind a-head.

PROP. XV.

To lye to under the Courses.

When on account of the violence of the wind, or the fear of danger, or of any other reason, it is thought convenient to lye by : If then the ship cannot come to an anchor, nor lye to under her top sails, they then try under her courses ; that is (as before with her top sails) they so dispose her lower sails, that she may make little or no way.

1. The top sails being furl'd, and the lower sails trim'd close, keep as near the wind as possible, without hazard of taking the wind a-head, that so the ship may make very little head-way, and only fall off in a line between the direction of the wind and the rumb of the course.

2. A ship will still make less way, if the main sail be likewise furl'd, and only the fore sail and mizen set, or the mizen alone.

3. Sometimes the main sail only is made use of, and then the ship will move only by jerks as it were, and fall too near the line of the wind. She will thus make but little way, but then she will labour very much. The rudder will be but of little service in this case ; but that the ship may labour the less, let the helm be so put to leeward, that the rudder may be nearly parallel to her course.

4. Some-

4. Sometimes the wind blows so hard, that a ship cannot bear any sail. In *Fig. 41.* such case, having furl'd all the sails, and squar'd the lower yards, brace the top-sail yards in the same manner as if the sails were spread, and put the helm hard over to leeward. Thus shall the ship move as it were by jerks, most commonly presenting her side to the wind, because when she is pretty much fallen off, she gets head-way, and the rudder B R will bring her again to the wind, and when she has gain'd too much to windward, she will fall a-stern, and the rudder B R will again throw her to leeward. If the helm be put over to windward, the rudder will bring the ship about, since if she be much fallen off, and has got head-way, the rudder will make her fall still more off; and if she comes too close to the wind, and falls a-stern, the rudder will still bring her more to windward. From whence it follows, that by means of the rudder a ship may be turn'd, though she has not a single sail spread.

5. If when a vessel is thus only driving with her masts and yards, it is thought proper to let her go before the wind, when the ship comes into the line of the wind, right the helm, and manage it altogether the same as if the vessel were under sail, for in such hard gales especially, the hull and rigging are in effect a sail. And thus driving before the wind, a ship will sometimes make such great way, that she may run much hazard of being lost, if she hath not sufficient sea room.

P R O P. XVI.

To govern a Ship with the Yards.

1. It is easy to govern a Ship with the sails, since some of them serve to make her fall off, and others

others to bring her to the wind; and since the yards serve in some degree as sails, a ship may in like manner be govern'd with her yards.

2. When in fine weather it is thought convenient to change the place of a ship's riding, in a road where there are many other vessels; unfurl the mizen, and mizen-top sail, and in weighing the anchor, let the yards be brac'd as much as possible opposite to the place where the ship is to fall. Then when the anchor is up, and the ship sufficiently fallen off to take the proper direction, set the yards in all respects as if the sails were spread; if the ship comes too much to the wind, hale up the mizen, and brace the fore yards close in to windward. If she falls off too much, hale out the mizen and mizen-top sail. If the ship has too much head way, check her by laying the mizen-top sail a-back. If she has too little head-way, increase it by assistance of the mizen and mizen-top sail. In this manner you may traverse a road as you please, and moor a ship just where you have a mind. But for the greater security, they commonly send out a boat with a small anchor, in case of a calm or a contrary wind.

R E M A R K.

Many other common practices in the working of a ship might be added to these above explain'd; but as they have nothing particular to be accounted for, I shall pass them over, that I may not tire my reader with tedious repetitions.

P A R T



P A R T III.

Of sailing from one Place to another at a distance.

P R O P. XVII.

To come to sail.

1. **A**T a proper time to go to sea, having un-moor'd your ship, in heaving up to your other anchor, steer your ship right with the anchor, and having recover'd the buoy and brought your ship a-peek, loose your top sails, and set them, bracing the main yard and main-top sail up sharp, and your fore top sail a-back, to flat her off to that side you would cast her; at the same time haling out the mizen to bring her the more readily to again; in this manner if you have nothing to oblige you to make sail, keep her till your anchor is stow'd, when you may ware her to her course, and then make use of what sails you think proper.

2. If in bad weather you are oblig'd to come to sail, and in doing it, are in danger of falling upon some rock as A, carry out a small anchor on that bow your danger lies, and bring the hawser in abaft on the same quarter,

Fig. 42.

and

and make him fast, which having done, vere away the cable D, till the ship is fallen off so far as that you may serve your self with such sails as are proper for the weather, which, when you can do, cut away your cable and hawser.

3. If time and weather will permit, it would be better to carry an anchor farther out a head, after having hove in as much as may be on the anchor down, and come to sail from the anchor so carried out, from whence you will probably have room to cast.

4. When the weather permits you not to come to sail with the top sails, you may with the fore sail and mizen.

5. When you are obliged to cut, in order the more readily to come to sail, be sure you do it not till your top sails are hoisted, and brac'd for casting, lest you fall to leeward, and lose more time than if you had hove up your anchor. Remember also to leave a buoy on the end of the cable, that you may take it up again if opportunity offers.

P R O P. XVIII.

Of gaining as much as may be to windward.

1. If a ship had as much difficulty to divide the water with her head, as with her sides, as would be the case were she round, she could then
Fig. 43. no way gain to windward. For let the ship be A, the line of the wind B A, the perpendicular to the wind C A, the sail D A, its direction A E. If the vessel A were round, she would continually keep the direction A E of the sail,

fail, and consequently fall off from the line AC ; which is called falling to leeward or making lee-way (*Def.* 4.)

2. If on the contrary, a ship could not at all divide the water with her sides; but always kept the line she looks in, without making any lee-way, she would continually gain to windward when she looks above the line AC , as in the line AF , and what she gains to windward will be measur'd by FG , the sign of the angle FAG , provided her absolute motion be measured by the line FA . That is to say, the product of the sign of the angle FAG by FA , the sign of the angle FEA , or FAD , will always be what the ship gains to windward in the course FA . But this product will always be greatest when the two signs are equal; therefore the ship A will always gain most to windward when the line FA , divides the angle CAD into two equal parts.

Or, if you like better so to express it, the point F in the middle of the arch AFC , is the most distant point from AC , or more to windward than any other point as H , in the same arch; and moreover the ship will arrive as soon at the point F , as at the point H . (*Prop.* 2. 7.) Therefore she will gain most to windward, when her course AF , equally divides the arch AFC , or the angle DAC .

3. Lee-way makes no alteration in this rule; for if a ship making lee-way, shall only arrive at the point I , in the line FE , in looking up to the point F ; in looking up to the point H , she shall only reach the point K , of the line HE ; and the lines FH , IK , shall be parallel (by *Prop.* 1. 7.) Therefore

fore if F is to windward of H, I shall be to windward of K (by *Def.* 4.)

4. Let us go on supposing the ship to make no lee-way; draw BD the sign of the
Fig. 44. angle BAD, which the situation of the sail makes with the wind. Since the signs DB are to one another, as the roots of the impulsions of the wind upon the sail (by *Sup.* 8.) in its different situations; and that the different velocities of a ship's sailing are also to one another, as the roots of the same impulsions (by *Sup.* 7.) the different velocities of sailing shall be to one another, in the different situation of the sail, as the sign DB; and consequently the velocity of a ship may always be express'd by the sign DB, in supposing the sign total to express the velocity of a ship sailing before the wind. Make then AE equal to DB; and having describ'd the semicircle ACE; from the center H draw HF perpendicular to AC, which shall divide the arch AFC equally in the point F (by *Euc.* 1. 3.) and cut the line AC in the point G. But the line AF is the most advantageous course for the ship to gain to windward in the situation of the sail DAB (by the prec.) therefore the line FG shall be all that the ship is able to gain to windward in the situation DAB. Upon which we may make the following reflections.

1. If the angle DAB is just 30 degrees, FG shall be exactly $\frac{1}{6}$ of radius.

Demonst. DB, or AE being the sign of 30 degrees, will be $\frac{1}{2}$ the radius, and since all the angles of the triangle HAF are of 60 degrees, FA will be equal to AH, or $\frac{1}{2}$ of radius. But FG being the

the sign of 30 degrees, will be the half of A F ;
it will therefore be $\frac{1}{8}$ of radius.

2. If the angle D A B be more than 30 degrees,
F G will be less than $\frac{1}{8}$ of radius. Let us call d
the difference between the sign of 30 degrees, and
the sign D B, which we suppose greater.

Demonst. A E being equal to $\frac{1}{2}$ radius with d ,
and consequently H F being equal to $\frac{1}{4}$ of radius,
and $\frac{1}{2} d$. Moreover H G being the sign of above
30 degrees, will be equal to the $\frac{1}{2}$ of H A, or $\frac{1}{8}$
of radius, and $\frac{1}{4}$ of d , and besides of a magnitude
which will be to d , as A H to the sign total, or
more than its fourth ; therefore H G shall be more
than $\frac{1}{8}$ of radius, and $\frac{1}{4}$ of d , and consequently if it
be subtracted from H F, the remainder F G will
be less than $\frac{1}{8}$ of radius.

3. If the angle D A B be less than 30 degrees,
F G will be less than $\frac{1}{8}$ of radius. Let us again call
 d the difference between the sign of 30 degrees, and
the sign D B which we suppose less.

Demonst. H F will be $\frac{1}{4}$ of radius less $\frac{1}{2} d$. More-
over H G will be $\frac{1}{2}$ of A H less a magnitude, which
will be to d as H A to radius ; that is to say, less
than its fourth ; therefore A G will be equal to more
than the $\frac{1}{2}$ of A H less $\frac{1}{4}$ of d , or will be equal to
more than $\frac{1}{8}$ of radius, less $\frac{1}{4}$ of d , and consequently
if it be subtracted from F H, the remainder will be
less than $\frac{1}{8}$ of radius.

C O R O L L A R Y.

From whence it follows, that if the ship makes no
lee-way, the situation D A B, the most advantageous
to gain to windward, ought to be just 30 degrees.

5. To

5. To find what alteration *lee-way* will make in this rule. Draw EL , and HM , parallel to CA , and continue FG , till it meets EL , in the point L . Again, draw CE , in proportion to EA , as DB to BA . Then supposing EI to FE , as the difficulty of the ship's dividing the water by her head, to that of dividing it by her side; and as any magnitude d (which we call *lee-way*) is to the sign total. Lastly, supposing IK parallel to CA ; in the situation DAB of the sail with the wind, the line FG less FK , will be what the ship gains to windward, knowing therefore FK , her advance to windward may be known; for FG is easily known as above explain'd. Thus therefore may be found FK . Since the angle CAE is equal to the angle DAB ; the sign total AB , is to DB ; as AE equal to DB , is to CE , which by this means will be known; and consequently FL may be found, which is the half of CE , and the half of AE . Therefore since $EF:EI::LF:LK$, FK is consequently discovered.

C O R O L L A R Y.

As it may be known what a ship gains to windward in every situation of the sail, it will be found that the most advantageous situation for that purpose, is when it makes the sign DB , equal to half the radius, less a magnitude or quantity, which is to the sign total; as the *lee-way* d , is to the sign total more the *lee-way* d . For in augmenting or diminishing ever so little this situation, GK will be found less.

L E M M A.

If A being greater than B , does not exceed it more than B does C ; the square of B shall be greater

greater than the product of A into C (by *Eucl.* 16. 6.) Since A will have a lesser ratio to B, than B to C.

P R O P. XIX.

To find the most advantageous situation of a Sail for a Course given, when a Ship makes no lee-way.

1. Let A B be the line of the wind, A F the course, and D A the sail. Draw *Fig. 45.* A E perpendicular to the sail, and equal to the sign of the angle D A B, and upon A E describe a semi-circle cutting the course A F, in the point F, so shall A F be the velocity of the ship, in the situation of the sail D A B.

2. The angle F E A being equal to the angle F A D; the sign total will always be to the line A E the sign of the angle D A B, as the sign of the angle F A D, to the line A F; and consequently; the product of the sign D A B by the sign F A D, being divided by the sign total, will give the velocity A F.

3. This product will always be greatest when the two angles D A B, F A D are equal (by *Lem. prec.*) since in augmenting the one, its sign is only increased, in proportion as the other is diminished; so that the velocity of the ship is always greatest, when the sail A D divides the angle F A B of the course with the wind, into two equal parts.

R E M A R K.

This rule then serves for gaining the most that may be to windward in a given course, when a ship is supposed to make no lee-way; because in that case

to go most swift, is the same thing as to gain most to windward. This rule therefore is of great service in practice, since lee-way is very often insensible.

P R O P. XX.

Of the alteration in Velocity, which lee-way will cause in the foregoing Proposition.

1. If A F be the rumb line upon
Fig. 45. which the ship ought to sail, the sail shall be still in the most advantageous situation for velocity upon such rumb, when it equally divides the angle F A B.

Demonst. Let us suppose the sail to divide the angle F A B unequally, then if the vessel having no lee-way, would arrive but at the point H, in the time she would have got to the point F; (by the prec.) with lee-way she will only obtain the point K of the perpendicular H I, in the time she would have come to the point G of the perpendicular F E.

2. If the ship keeping the rumb A F, is carried by her lee-way to the point G of the perpendicular F E, when the sail equally divides the angle F A B; the angle D A B cannot be augmented without retarding the ship's arrival at the point G.

Demonst. If the angle D A B be augmented, and the ship keeps the same rumb A F, she will come but to the line H I, in the time she would have got to the line F E; but as her lee-way would carry her on in a line below the line A G, it is therefore necessary she should run more to windward, for which reason at the time she should have gain'd the line F E, she will be found in a line still nearer the point

point A, than the line H I, and consequently will only arrive at some point nearer A, than the point K, at the time she should have arrived at the point G.

3. If the angle D A B be diminished, the ship will then sooner arrive at the point G, and it will be easy to find the velocity A G in every position of the sail. For the sign total will always be to the sign of the angle D A B; as the sign of the angle F A E the complement of F A D, to F E; therefore F E may be known, and consequently F G, which is to F E, as the lee-way, to the sign total. Farther, the angle G A F may be known; for the tangent of the angle E A F, is to the tangent of the angle G A F, as E F to G F. Lastly, A G may be found; for the sign of the angle G A F, is to G F, as the sign total to A G.

C O R O L L A R Y.

The angle D A B, which shall be the most advantageous, may be found by a trigonometrical calculation, that is, such an angle as cannot be augmented or diminished, without lessening A G. For example, suppose it were requir'd to find the most advantageous situation of the sail for a ship, whose lee-way is to the sign total, as 1 to 10, and to keep the course A G, making an angle G A B with the wind of 100 degrees. I begin by supposing that the angle D A F ought to be 51 degrees, that is a little more than half the angle G A B. Its complement F A E will be 39 degrees, subtract the logarithm of 10 from the logarithm of the tangent of 39 degrees, and the remainder will be the logarithm of the tangent of the angle G A F, which will be 4 degrees 38'; this added to the angle F A D, gives

gives $55^{\circ} 38'$ for the angle GAD ; and consequently the angle DAB will be $44^{\circ} 22'$. Add the logarithm of $44^{\circ} 22'$ to the logarithm of 39° and from the sum subtract the logarithm of the sign total, the remainder will be the logarithm of FE , from which must be taken the logarithm of 10 to get the logarithm of FG . Then adding the logarithm of the sign total to that of FG , and subtracting from the sum the logarithm of the angle GAF , the remainder will be the logarithm of the velocity GA , for the situation which makes the angle DAB $44^{\circ} 22'$.

9.908369	Log. Tan. 39 degrees
1.000000	Log. 10
8.908369	Log. Tan. 4 deg. 38'
9.79887	Log. Sine 39 degrees
9.84463	Log. Sine 44 deg. 22'
19.64350	
10.00000	
9.64350	Log. FE
1.00000	
8.64350	Log. FG
10.00000	
18.64350	
8.90692	Log. 4 deg. 38'
9.73658	Log. AG

Do the same in augmenting, or diminishing the angle DAB till it cannot be more increas'd or diminished, without lessening the velocity AG , and you will obtain the most advantageous situation.

After this manner the following table is made, and so may be calculated for every possible case.

A Table

A Table of the Situation of the Sail for the several Courses therein given.

Angle of the Wind with the Course given	Lee-way					
	$\frac{1}{5}$		$\frac{1}{10}$		$\frac{1}{20}$	
	Angle of the Wind with the Course to be kept	Angle of the Wind with the Sail	Angle of the Wind with the Course to be kept	Angle of the Wind with the Sail	Angle of the Wind with the Course to be kept	Angle of the Wind with the Sail
Degr.	Degrees	Degr.	Degrees	Degr.	Degrees	Degr.
170	169	84	170	85	170	85
160	158	79	159	79	160	80
150	147	73	148	74	149	74
140	135	66	138	67	139	69
130	124	60	127	62	129	64
120	113	54	117	57	118	58
110	102	48	106	51	108	52
100	90	41	95	45	98	47
90	79	33	84	39	87	41
80	67	26	73	34	77	35
70	55	18	62	27	66	31

P R O P. XXI.

Of the alteration which Lee-way will make in the foregoing Propositions, when a ship is to gain more to windward.

1. If the course be determined, there will be no alteration in the last proposition.

2. If only the rumb line $A F$ be determined, the angle $D A B$ must not be greater than half the angle $F A B$.

Demonst. The angle $D A B$ being above the half of $F A B$, the ship would only gain the point L , in the time she should have got to the point G , if the angle $D A B$ had been but half the angle $F A B$ (by the prec.) which point G , must always be to windward of the point L , since if it be required to gain to windward, the angle $F A B$ must be acute.

3. In making the angle $D A B$ less than half of $F A B$, the ship will gain to windward, since the angle of the lee-way becoming less, the ship may arrive at the point N , in the time she would have come to G , if the angle $D A B$ had been half of $F A B$.

4. It is easy to determine what a ship gains to windward upon every situation of the sail; for having drawn the perpendicular $G M$ upon $A B$, the line $M A$ will be the ship's gain to windward; and the sign total will always be to $A G$, as the sign of the angle $M G A$ the complement of $G A B$, to the line $A M$.

Corol. The most advantageous situation of the sail for gaining to windward, may therefore be also found, and thrown into tables serving every possible case, as in that which follows.

A Table of the Situation of the Sail for gaining to Windward upon the several Rumb Lines therein given.

Lee-way	$\frac{1}{3}$	$\frac{1}{10}$	$\frac{1}{20}$
Angle of the given Rumb with the Wind	Angle of the Sail with the Wind	Angle of the Sail with the Wind	Angle of the Sail with the Wind
Degrees	Degrees	Degrees	Degrees
85	0	19	19
80	16	20	24
75	18	21	33
70	20	23	31
65	23	26	30
60	22	25	26

P R O P. XXII.

To find the proper Rumb a Ship should keep, in sailing from one fix'd Place to another.

1. If the vessel has no lee-way, let her head point directly to the place she is to sail to.

2. When a ship has lee-way, turn her head to windward of the point she is to make, in the following manner. Suppose the ship *Fig. 47.* A, the line of the wind B A, the point she is to sail to, C; then must the ship range upon some other line as A D, and there will be two ways of observing whether she makes too much or too little to windward. 1. Take notice of some object as E, which answers directly with the point C, and if when the ship has sailed some length, the object still continues to answer directly with the point C, it is plain the ship keeps the line A C E, and will run directly upon the point C. But if after some time sailing, the object E opens to windward of the point C, you may be sure the ship's head points too much to windward, and that the ship will run to windward of the point C, unless she falls off a little. If the object E opens to leeward of the point C, then 'tis certain the ship falls off too much, and will not weather the point C. 2. Set the point C by the compass, and if after some time sailing, the point C continues to bear the same, the ship then keeps the right course; but if the point C falls to lee-ward, the ship runs too much to windward; on the contrary, if the point

point C appears more to windward, the ship then falls off too much.

3. In the same manner it may be known whether a ship will double a Cape; or whether she will gain to windward, or fall to leeward of another ship riding at anchor, &c.

P R O P. XXIII.

To find the proper Course for chasing a Vessel to Leeward.

Suppose the ship A were to chase the ship B, and F A the line of the wind. *Fig. 48.*

1. If the ship A were to bear right down upon the ship B, she would describe, in approaching her, a curve line, till she falls into her wake, and would run a hazard of not coming up with her at all; both as she would have more way to run, and would lose the advantage of the wind.

2. The ship A must then look to windward of the ship B, and range upon some line as A E, wherein she may come up with the ship B at the point E. But to know that line, it must be considered, that if the vessel A comes up with the vessel B at the point E, she must run through the line A E, in the same time that the vessel B is running through the line B E; and consequently imagining the lines C D parallels to A B, to cut the lines A E, and B E, into proportional Parts, (by 2. 6. of *Eucl.*) the two ships will arrive at the same time upon each of these parallels, and consequently with regard to each other, will con-

tinue on the same rumb, as when they were on the line A B.

3. It is then easy to know, if the line A E, upon which the ship A ranges, is a proper course for meeting the ship B at the point E, by repeatedly setting the ship B by the compass, at little intervals of time. For if the same bearing continues, it is a certain sign the two ships arrive at the same time upon each of the lines C D, and will consequently meet at E; but if after some time, the ship B falls to leeward, it may be concluded that the ship A keeps too much to windward; on the contrary, if the ship B is found more to windward, after having made a small run, it shews that the ship A falls off too much, and must keep closer to the wind, not to fall to leeward of the ship B.

R E M A R K S.

1. Though the ships A and B sail equally well, yet if the ship B continues sailing close upon the wind in the line E E, the ship A, which is to windward, may come up with her by some other line as A E. Since the ship A sailing with a larger wind will run swifter, and may therefore run through the lines A C, while the ship B is running thro' the lines B D.

2. In like manner the ship A may come up with the ship B, by many different lines, if in falling off, she increases her velocity in the same ratio as the lines A C.

P R O P.

P R O P. XXIV.

To find the proper Course for a Ship to cut, or cross the Way of another, to windward of her.

1. The ship A being to leeward of the ship B, may possibly be so good a *Fig. 49.* sailer, that in tacking on any line as A E, she may run through the parts A C, while the ship B is running through the correspondent parts B D, and consequently come up with her at the point E. Whether A E be the proper line, may be tried as before, by frequently setting the ship B by the compass; for if she be found still to bear upon the same point, it shews the two ships answer each other by the parallels C D, and that they will meet at the point E. But if the ship B falls to leeward, the ship A keeps too much of the wind; on the contrary, if the ship B gains to windward, the ship A falls off too much; and therefore if she can lay no nearer, she will not be at all able to cut or cross the way of the ship B.

P R O P. XXV.

To find the Point where a Ship ought to Tack, to cut or cross another to windward of her.

1. If the two Ships A and B, sail with equal velocity, they cannot cut or cross each other, unless one be to windward of the other. *Fig. 50.*

2. If the ship A, which is to leeward, out-falls the ship B, she may cross the other before she gains the wind, and the point where she is to make her tack for that purpose, may be determined, if the time she would take up in running through a line equal to the space between them, is nearly known, as thus ;

3. Suppose the ship A is to run the course A D, and the ship B to run the course B E, parallel to A D ; and that the time the ship A would take to run thro' a space equal to the distance A B of the two courses, were nearly known. Observe the time which has past since the ship A answer'd to the ship B, by the line A B perpendicular to the courses, and that wherein she answers by the line C H, which makes the angle H C A 45 degrees ; and from that time, subtract the time the ship would have taken in running through a line equal to A B, then will the root of double the square of the remainder, be the time that the Ship A should continue on her course from the point C, before she makes her tack to cross the course of the ship B. Continue A B, and C H, till they meet in the point G ; and make C D, H E, equal to G H ; then draw D G, which shall cut H E, in the point I ; lastly, compleat the parallelogram G C D F, and draw H L parallel to B A.

I say, 1. That the point D, shall be the point where the ship A ought to tack, according to the rule given.

Demonst. Since in the rectangled triangle C A G, the angle C is 45 degrees, it will be equal to the angle G, and the lines A C, A G, will be equal ;

equal ; as also B H, B G ; and C L, L H, or A B. Then since from the time that the ship has taken to run through the line A C, the time she would have taken to run through the line A B, or C L is taken ; the remainder will be the time she has taken in running through the line L A, or H B ; and the root of its square doubled, will be the time she must take up in running through G H, or C D : and consequently the point D, must be the point where the ship A must tack, according to the rule given.

I say, secondly, That the ship A, tacking at the point D, shall meet the ship B, in the point E.

Demonst. $CD : HI :: CG : HG$; or $:: CA : HB$; then since the ship A has run through the line A C, while the ship B has been running thro' the line B H ; she will run through the line C D, while the ship B runs through the line H I. Likewise since $DE : EI :: DF : FG$, or $:: CG : or :: CA : BH$, the ship A shall run through the line D E, while the ship B runs through I E, and both shall come at the same time to the point E.

4. It is plain enough, that in practice the ship A should run something beyond the point D, by reason she will lose some time in tacking.

P R O P. XXV.

Remarks upon giving Chace.

1. If the distance A B between the courses of the two ships is small, it *Fig. 50.*
G 5 will

will be best for the ship A to hold on her course, till in tacking she can cut the other.

2. If the distance A B is very great, the ship A ought not to stand so far on one tack, as in changing her board to expect to cut the ship B, lest she should run too far, and so the ship B escape, either by being favoured by the wind, or imperceptibly making some alteration in her course.

3. Neither ought a ship to tack, every time she shall see the ship she chases about; by reason of the time she will thereby lose.

4. I think it may be laid down for a general rule, *always to tack upon the vessel in chase*: that is to say, that the ship A ought not to tack, till the ship B is fix'd in her course after tacking, by which means she will never be distanc'd from the ship in chase; and if the wind does not shift, will probably fetch her upon the second tack; or if the wind does shift, if to her advantage, she will be ready to reap the benefit of it; or if on the contrary, she will be the readier to recover the disadvantage.

5. In regard to the ship that is chased, she ought, 1. To make the best of the inadvertencies of her adversary; she should often change her course, and keep to that she finds most to her advantage; that is to say, that which distances her most from her enemy: 2. Not to be too solicitous to keep close upon the wind, if she sails better with a large wind; for as the wind often changes during a chase, she may possibly find herself to lee-ward, by keeping the wind too close.

3. Above

3. Above all things avoid keeping up to the wind, when you are very much to leeward of your enemy; on the contrary, go a little more large away than he, unless he steers directly down upon you, for in that case you must ply to windward.

P R O P. XXVI.

Of boarding a Ship.

1. If the vessel you would lay aboard be at anchor, you may anchor on his buoy, and veer away your cable till you fall aboard him; but then too he may cut away, and so you may lose your labour.

2. Neither would I advise the furling your sails in falling aboard him; because it will be easy for him to keep you off with his booms and boats.

3. This way then I would prefer. First, I would get my sprit-sail yard fore and aft, then with my top sails a trip, I would lay him aboard on the bow. In this manner I should have more time and means to grapple him fast.

4. If the ship you would board is under sail, and keeps her wind, it would be best then too, to board her on the bow, but it must be to windward, else she may easily avoid you, by keeping her wind close: If in the instant you lay her aboard, she wares from you, you must ware after her, or she will shoot a-head of you, which if you cannot avoid, be sure you keep the weather-gage of her, for the next opportunity of boarding.

5. If

5. If the ship you would board, goes before the wind, and you can out-fail her, range up along her side, before you sheer aboard her.

6. When your Ship is under fail, you may easily avoid being boarded. For 1. If the enemy would board you on your bow to windward, you may ware short round; and if the enemy wares too, you may take luff for luff, which will infallibly put her to leeward of you; if the enemy keeps the wind, wait till she has past you a stern, and then tack again to the wind upon the same board you were before, which will entirely prevent his boarding you. 2. If he would board you on your bow to leeward, keep as close as possible to the wind, so shall the wind of your ship support you, and becalm him, which will consequently make him fall to leeward, and a stern. 3. If your enemy would board you on the poop, it will be easy to avoid it, by giving your ship ever so small a sheer the contrary way.

7. If two ships friends, come with a large wind one against the other, they may avoid running foul, if the one falls off ever so little, while the other keeps her wind; but if one is close upon a wind, the other ought to fall off, because a ship close haled is not always so ready to ware.

8. If a ship is coming athwart you a-head, you may avoid it, by laying all your fails aback, if you are to leeward, but if you are to windward, she ought to ware short.

9. If in sailing on a wind in a line of battle, the ship A a-head be taken at stays, she will be in danger of falling aboard

Fig. 51.

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aboard the ship B which follows ; in this case the ship B must not put to stays for fear of falling on a third, and unless she wares a great deal, so as to run out of her line, she will only bear up into the others way, by the line B D ; she should therefore luff up, even to touching into the wind, from whence these two things will follow, 1. The ship B will lessen her way. 2. She will get out of the line in which the ship A falls, by keeping the line B F.

10. If the ship A being at anchor, is like to be run aboard by the ship B, *Fig. 52.* the ship B ought to ware short round ; but if they are obstinate and will not, the ship A ought immediately to veer away her cable. If the ship coming on the ship A, be close on her wind as C, she ought speedily to lay all aback, unless she is so much to windward as D, for then she ought to keep as much of her wind as possible, so as not to shake all her sails, lest in laying aback she drive foul of the ship A.

11. If in a calm the current throws the ship B upon the ship A at anchor, *Fig. 53.* the ship B must be tow'd a stern with boats ; unless she be so far advanc'd athwart her, that it would be easier to tow her clear a-head.

12. If the ship A at anchor, drives upon the ship B likewise at anchor, *Fig. 54.* they must both veer out cable, for it is the only means to bring him up that drives ; it will be also proper for him to carry out another anchor.

13. If

Fig. 55. 13. If the ship A drives, and the current C D throws her upon the ship B at anchor, where the channel is of a sufficient breadth, the ship A must veer out cable, and back her mizen-top-sail, to make her fall towards E, till her anchor takes, or she falls beyond the ship B. In this case, as the cables will probably cross each other, one must cut, or veer it quite out, with a buoy at the end.

14. There may be many other circumstances with relation to the boarding of ships, which might perhaps require particular rules; however, these laid down will sufficiently lead to whatever else may occur in practice.

P R O P. XXVII.

Of running into Land.

1. If you are obliged to run in upon an unknown coast, make as little sail as possible, sending out your boats to sound a-head, and at the same time keep the lead going on both sides aboard; when you think you have a good birth for anchoring, brace too to give time for the boats to sound all about; you may then, if you find the place convenient, anchor, but not moor, till you have better examined it, sounding all around, and setting the neighbouring capes, to know if you have safe riding. Lastly, if you have time, make your self perfectly acquainted with the place, and lay down a plan thereof.

2. If you are acquainted with the land you are running into, set the head-lands you know, to find the

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the exact point where you are, then running in with small sail, observe the proper marks which lead you to good anchorage.

P R O P. XXVIII.

To bring a Ship to an Anchor.

1. In fine weather, drawing near your anchoring-place, get your anchor clear, and your buoy ready to stream, also take a range with the cable about the bits, in proportion to the depth of water you are to anchor in; at the same time furl your main-sail, hale up your fore-sail, and lower a little your top-sail yards. Lastly, when you are come to your anchoring-place, hale out the mizen to bring up the ship to the wind, then clewing up one of the top-sails, brace too the other to stop her way, which when she has wholly lost, and begins to fall, let go your anchor, and veer away the cable till your anchor is a-ground, which if you have any wind, and the ship will fall, keep still veering, till you have as much out as you think proper; if the ship will not easily fall a-stern, you may help her with the mizen-top sail aback.

2. If there be any currents against the course, you must not hale up all your sails till at the place of anchorage, otherwise the currents will soon carry the ship away again.

3. You may also in fair weather, come to an anchor with all your sails abroad; laying all aback to stop the ship's way the moment before you come to. But this is not so convenient, unless you have a great many hands to furl all at once.

4. In

4. In bad weather, it is most proper to come to with the fore-fail only; by bracing which aback, you may stop the ship's way. 2. In such case, take two turns with your cable about the bits. 3. Let go the weather anchor, lest the vessel in falling should rub the cable against her cut-water. 4. Veer away a great scope of cable to ride her.

P R O P. XXIX.

To Moor.

1. In places where the tides are commonly stronger than the winds, you moor according to the set of the tides; that is to say, if the tides set east and west, your anchors ought to lie east and west.

2. Ships generally moor with a large anchor and a less, commonly the small bower; giving the greater scope of cable to the best anchor; which is always laid where the most danger is expected.

3. In places where the tides are very small, and the winds generally strong, you should moor in a line perpendicular to the wind, that so both your cables may bear alike; which cannot be done in a tide, where there are two motions entirely opposite.

4. Most commonly the anchor you moor with is carried out with the boat, and so dropp'd as to answer right with the larger anchor a-head; but if it be necessary, by reason of bad weather, to moor with too large anchors, after having let go your first, carry out a small anchor in your boat, something farther than you design to let drop the second,

second, and heave your ship by the said small anchor, till you come to the proper place to let go the second. In this case there should be but a small range of cable allowed to the second anchor, lest falling all at once to the ground, it should break or bend; but biting it short, pay out the cable gently, as you recover that of the first anchor.

5. In fair weather, coming to an anchor, you may moor in this manner: Haul up your couries, and take in the main-top-sail, then letting go your anchor without biting it, and with a good range, pay out the cable very fast, and shoot your ship over with the fore-top-sail, till you are where you would let go the other anchor, which do with the former precautions; after which as before, heave in the cable of the first anchor, as you veer out this.

6. Where you have strong tides, 'tis very easy to moor, by veering away your cable upon the strength of the tide, till it is proper to let go the other anchor; then in heaving in the first cable, you veer away the second.

R E M A R K S.

1. The reasons of several of the rules above given are omitted, because they are self-evident.

2. Many things too I have let pass, that I might not run this Tract into too great a length; besides, that for the most part, those things which are omitted, are such as will be easily learn'd in practice, tho' very difficult to be explain'd.

3. Those operations which depend more immediately on Mechanicks, may serve as corollaries to the Tract upon that subject.

Before

Before we proceed to the Explanation of Terms used in this Work, I must desire the Reader to observe what was said in prop. 4. that the head-sails hinder a ship from yawing, is not to be understood, as if you were to increase the head-sails, that she might yaw less; it being certain, a ship fetches the greater sheers, the greater way she has thro' the water. It is therefore only meant, that the head-sails correct the yaws a ship will necessarily take in a sea; so that if a ship were thrust forward in a certain velocity by her after-sails, she would sheer more, than if thrust on with the same velocity by her head-sails only. So also in 4. of the same proposition, when it is said the head-sails bring a ship to, it is to be understood as there explained, for the head-sails being aback, flat her off from the wind.



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AN ALPHABETICAL
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Occur in the foregoing TRACTS; or
are occasionally used in this, for the
Explanation of others.

A



FT, or ABAFT; is a sea-term
to distinguish between things done, or
plac'd from-wards the stem or fore-
part of a ship, towards the stern, or
hind-part: As when they say, come
ast or go *ast*; that is, go towards the stern.
Haul the sheet *ast*: The mast hangs *ast*; that is,
towards the stern.

Astward, the hinder part of the ship.

ALTI-

ALTITUDE of the sun, or a star. Height above the horizon.

ANCHOR, is a massive iron, which being cast into the sea or river, by sticking fast in the ground, prevents a ship's being carried away with the wind or current. It consists of a shank or beam, with flocks at one end to enter the ground, and a stock of wood at the other, serving to guide the flocks; it has also a ring, by which it is fastened to the cable.

There are several sorts of *anchors*, differing only in weight, which is according to the burden of the ship.

Sheet-anchor, is the greatest of all that belong to a ship, and is never used but in great necessity, as being their utmost refuge, when forc'd to ride on a lee-shore.

Bow-anchor, *first* and *second bower*, or *best* and *small bower*, are such as the ship in fair weather may ride by.

Kedge-anchor, or *kedger*, used in calm weather, in a low stream, or to kedge up and down a narrow river, lest the wind or tide should drive the ship ashore. See **KEDGING**.

Grapples, or *Grapplings*; are the smallest of all the *anchors*; they have four flocks, but no stock. Their use is for a boat to ride by; or to throw into an enemy's ship in a close engagement, to catch hold of the gratings, rails, &c. in order for boarding her.

To ride at anchor, is said of a ship which is held fast by her *anchors*, so as not to be driven with either wind or tide.

To cast or *drop anchor*, is to let it fall, to stop the course of the ship.

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To weigh anchor, is to get it up, in order to set sail.

To shoe an anchor, is to put boards fitted for that purpose, on the flook, that the anchor may the better hold in soft ground.

The anchor is foul; that is, the cable is hitch'd about the flook, by the turning about of the ship.

The anchor is come home, is said when it does not hold the ship, but that she drives away by the violence of the wind or tide.

The anchor is a-peek; that is, the anchor is right under the hawse (or hole) through which the cable belonging to that anchor runs out.

The anchor is a cock-bell; that is, hangs right up and down by the side of the ship, ready to be dropt.

Pudding of the anchor, are those ropes which are wound round the ring, to save the clinch of the cable from being gaul'd by the iron.

B

BEAK, or *Beak-head*; is that ornamental projection at the head of a ship, supported by the cut-water.

BEAM. The *beams* are those great cross timbers, which keep the ship's sides asunder, and support the decks. The *main-beam*, or *midship-beam*, or, as it is called by way of eminence, The *Beam*, is that next the main-mast, and is the measure of the ship's breadth.

BEAR; is a word us'd at sea in various senses, as in the following instances :

Bear up ; that is, let the ship sail more before the wind.

Bear up round ; that is, put her right before the wind.

Bears in with the land or harbour ; that is, the ship sails towards the shoar or harbour, with the wind large, or before it.

Bears off ; that is, keeps from the land.

The ship bears a good sail ; that is, having all her sails abroad in a gale of wind, sails upright in the water.

To bring the guns to bear ; that is, to lie right with the mark.

BEARING ; the point of the compass that one place bears from another.

To RELAY, is to make fast a rope in its proper place.

BIRTH, is a convenient place to moor a ship in ; as also a due distance observed between ships lying at anchor, or under sail.

BITTS, are two main pieces of timber standing pillar-wise abaft the manger, in the loof of the ship, with a cross-piece for belaying the cable when the ship rides at anchor. In great storms, to strengthen the *bitts*, and secure the bows, the cable is fastned to the main-mast.

BOARD, is a word variously used at sea ;

as,

To go aboard ; signifies to go into the ship.

To heave over board ; is to throw a thing out of the ship into the sea.

To slip by the board; is to slip down by the ship's side.

Board and board; is when two ships come so near as to touch one another; or when they lie side by side.

To make a board; is to turn to windward; and the longer your *boards* are, the more you work into the wind.

To board it up, is to beat it up sometimes upon one tack, and sometimes upon another.

She makes a good board; that is, the ship advances much at one tack.

The weather board, is that side of the ship which is to windward.

To board a ship, is to enter an enemy's ship in a fight.

BOOM, is a long piece of timber with which the clew of the studding sail is spread out; and sometimes the clew of the main-sail and fore-sail is *boom'd* out, that by spreading them the broader they may receive the more wind.

Booming; we say a ship comes *booming* towards us, when she comes with all the sail she can make.

BOW of a ship, is that part of her, which begins at the loof and compassing ends of the stem, and ends at the stern-most part of the fore-castle.

Bow-line, is a rope made fast to the leech or middle part of the out-side of the sail; it is fastned by two, three or four ropes like a crow's foot, to as many parts of the sail; only the mizen bow-line is fastned to the lower end of the yard; this rope belongs to all sails except the sprit-

sprit-sail, and sprit top-sail ; therefore those sails cannot be used close by a wind, for want of room to hale the bow-line forward by, since the use of the bow-line is to make the sails stand sharp, or close by a wind.

BRACES, are ropes belonging to all the yards of a ship, except the mizen, two to each yard, reev'd through blocks that are fastned to pennants seiz'd to the yard arms : Their use is either to square, or to traverse the yards. All these braces come aftward on, as the main-braces come to the poop ; the main top-sail braces to the mizen-top, and thence to the main shrouds ; the fore and fore-top-sail *braces* come down by the main and main-top-sail stays ; and so of the rest. But the mizen bow-line serves to *brace* to that yard ; and the cross-jack *braces* are brought forwards to the main shrouds, when a ship sails close by a wind.

BUOY, is a short piece of wood, or close-hoop'd barrel, fastned so as to float directly over the anchor ; and by that means it is always known whereabouts it lies.

Stream the buoy ; that is, let the anchor fall while the ship has way.

To buoy up a cable, is to fasten some pieces of wood, barrels, &c. to the cable near the anchor, that the cable may not touch the ground, in case it be foul or rocky, lest it should be fretted, and cut off.

C

CABLE, is a great rope fastned to the anchor, and proportioned to it ; serving to keep the ship fast while she rides at anchor.

Serve

Serve or plat the Cable ; that is, bind it about with ropes, clouts, &c. to keep it from gawling in the hawse.

To splice a cable, is to make two pieces fast together, by working the several strands of the rope one into another.

Pay more cable, that is, let it more out from the ship, that the boat which carries the anchor may row the easier, the *cable* lying slack in the water.

Pay cheap the cable, that is, put or hand it out apace.

Veer more cable, that is, let more of it run out.

A shot of cable ; when the *cable* is double in length, to make the ship ride the easier.

To quoil a Cable, is to roll it up in a ring.

To bend, or unbend a cable, is to fasten it to, or loose it from the ring of the anchor.

CAPSTAN. Ships have usually two (tho' both of the same form) distinguish'd by the names of the *main-capstan* and the *jeer-capstan* ; the *main capstan* is a great piece of timber in the nature of a windlass, but standing perpendicularly just abaft the main-mast, its foot standing in a step on the lower deck, and its head between the two upper decks, form'd into several squares with holes in them. Its use is to weigh the anchors ; to hoist up, or strike down the top mast ; to heave any weighty thing ; or to strain any rope that requireth a main force. The *jeer-capstan* is plac'd between the main-mast and the fore-mast, and serves to strain any rope, to heave upon the jeer-rope, or upon the viol, or hold off by, at the weighing of an anchor.

Capstan-bars, are the bars or pieces of wood that are put into the *capstan* holes to work the machine in heaving up any thing of weight into the ship, by

the help of as many men as can well stand at them.

Spindle of the capstan, is the main body thereof.

Whelps of the capstan, are short pieces of wood like brackets, made fast to it to keep the cable from coming too nigh in turning it about.

Pawl of the capstan, is a short piece of iron made fast to the deck, close to the body of the *capstan*; but yet so as that it hath liberty to turn every way, and against it the whelps of the *capstan* do so bear, that the *capstan* may be thereby stopt from turning or reverfing, and this stoppage is term'd *pawling the capstan*.

Man the capstan; that is, have all the hands necessary to heave at the *capstan* bars.

Come up capstan; or *launch out the capstan*; that is, slack the cable which you heave by.

CHASE, signifies the ship chased or pursued.

CHASER, is the ship in pursuit of the chase.

Stern-chase, is when the chase is right a head of the chaser.

To lie with a ship's fore-foot in a chase, is to sail the nearest way to meet her, and so to cross her in her way, or to come across her fore-foot.

CHESSE-TREES, are two small pieces of timber with a hole in them, on each side of the ship, a little before her loof; their use is for the main-tack to run through, and to hale it down to.

CLEATS; or, as some call them, *Chevils*, *Kevels*, or *Knevels*, are small pieces of wood nailed to the inside of the ship: Their use is to belay the sheets and tacks unto. *Cleats* are also pieces

pieces fastned on the yard arms, to keep the ropes from slipping off the yard.

CLOSE-HAWL' D; a ship is said to be *close-hawl'd*, when her sails are trim'd sharp, so as to sail as near the wind as possible.

CLEW *of a sail*, is the lower corner of it, to which are made fast the sheets and tacks.

COUNTER *of a ship*, is usually distinguished into upper and lower.

Upper-counter, is the hollow arching from the gallery to the lower part of the strait-piece of the stem.

Lower-counter, is between the transom, and the lower part of the gallery.

COURSE *of a ship*, is that point of the compass on which she sails; and is indeed the angle, that the rumb-line steer'd upon makes with the meridian.

COURSES, are the lower sails, particularly the main-sail and foresail.

CUT-WATER, is that thin projecting knee under the beak-head, and is so call'd, because it cuts or divides the water before it comes to the bow.

D

DECK *of a ship*, is a plank'd floor from stem to stern, whereon is plac'd the ordnance, and on which the men walk. Great ships have three *decks*, first, second, and third, beginning to account from the lower-most.

Half-deck, reaches from the main-mast to the stem of the ship.

Quarter-deck, is that aloft the steerage, reaching to the round-house.

F

FALL of a tackle, is that part of the rope which is haled upon.

Fall off; a ship is said to fall off, when in sailing she keeps not so near the wind as she should do.

FATHOM; a measure of six foot.

FORE and aft; that is, from stem to stern.

FRESHENS; the wind *freshens*, that is, blows stronger.

FURLE, (bind or make up) as to *furle* a sail, is to wrap up, and bind it close to the yard.

G

GAGE, a ship's *gage*, is so many feet as she sinks in the water, or so many feet of water as she draws; which seamen find thus: They drive a nail into a pike near the end, then putting it down by the rudder till the nail catch hold under it; for then as many feet as the pike is under water is the ship's *gage*.

Weather-gage; when one ship has the wind, or is to windward of another, she is said to have the *weather-gage* of her.

To **GRAPPLE**, is to hook fast an enemy's ship, in order for boarding.

GRAPLING. See **ANCHOR**.

GRIPE;

GRIPE ; the *gripe* of a ship, is the compass and sharpness of the stern under water, especially toward the lower part. The use thereof is to make a ship keep a good wind, and therefore sometimes when a ship will not keep a wind well, they put on another false stem to the true stem, to make her *gripe* more.

To gripe ; we say a ship doth *gripe*, when she is apt (contrary to the direction of the helm) to run her head more in the wind than she should. There may be two causes of this, the one when a ship is too deep a-head, so that by reason of the weight which presses down her head, she is unapt to fall away from the wind ; the other may be the staying of the masts ; for if she be a short ship, and draw much water, if her masts be stay'd too much ast, it will cause her head still to run into the wind.

H

HALE, signifies pull ; as to *bale up*, is to pull up ; to *bale in* or *out*, is to pull in or out.

HAWSES, are great holes in the ship's head through which the cables run, when she lies at anchor.

Bold hawse ; that is, when the holes are high above the water.

Fresh the hawse, or *veer out more cable* ; is when part of the cable that lies in the *hawse* is fretted or chafed, and it is requisite that more cable should be veered out, so that another part of it may rest in the *hawse*.

Fresh the hawse ; that is, lay new pieces upon the cable in the *hawse*, to preserve it from fretting.

Burning in the hawse ; that is, when the cable endures a violent stress.

Clearing the hawse ; when two cables that come through several *hawses* are twisted and entangled one with the other ; the untwisting of them is call'd *clearing the hawse*.

Thwart the hawse, or *rides upon the hawse* ; that is, when a ship lies thwart, or cross, or with her stern just before another ship's *hawse*.

HAWSER, is a great rope, or a sort of small cable, serving for various uses aboard a ship ; particularly to warp a ship by as she lies at anchor, and wind her up to it by a capstan, &c. Note, *hawfers*, like cables, are in proportion to the ships for whose use they are design'd ; for a great ship's *hawser* may serve for a cable to the sheet anchor of a small ship.

HEAD sails, are the sails belonging to the fore-mast and bolt-sprit ; for they govern the head of the ship, and do make it fall of ; and these in quarter-winds are the chief drawing sails.

HEAVE ; that is, to throw away ; as *heave it over board* ; that is, fling it over board.

Heaving at the capstan ; that is, turning about the capstan.

Heave and set ; that is, when a ship being at anchor, rises and falls by the force of the waves, she is then said to *heave and set*.

HELM, or *Tiller*, is that piece of timber which is fastned into the rudder, and so comes forward into the steerage, or place where he at the helm steers the ship, by holding the whip-staff in his hand. Large ships have commonly a wheel like those in cranes,

cranes, plac'd between the quarter-deck and coach, which has several advantages above the common method.

Bear up the helm ; that is, let the ship go more large before the wind.

Helm a mid-ship, or right the helm ; that is, keep it even with the middle of the ship.

Bear up round ; that is, let the ship go directly before the wind, in the middle, between her two sheets.

Port the helm ; that is, put the helm over to the left side of the ship.

Starboard the helm ; that is, put it to the right side of the ship.

Ease the helm ; that is, let the ship go more large, or more before the wind.

Feel the helm ; a ship is said to feel her helm when she steers readily.

HOISE, is to hale up any thing into the ship ; or getting up a yard, &c. as *hoise* up the yard ; *hoise* the water in, &c.

HULL of a ship, is the full bulk, or main body of a ship, from stem to stern, without either masts, or rigging.

To strike a hull ; that is, in a storm, to lie close in the sea, or tarry for some consort, bearing no sail, with the helm lashed a-lee.

To hull, or lie a hull, or hulling ; is said of a ship when either in a dead calm, (to prevent her beating the sails against the masts by rolling) or in a storm, when she cannot carry them, she takes all her sails in ; so that nothing but her masts, yards, and rigging are abroad ; the helm is lash'd fast to the

lee-side of the ship: In this condition, if she is a good sailer, she will lie easily under the sea, and make her way one point before the beam.

K

KEDGING, is when a ship is brought up or down in a narrow river, the wind being contrary to the tide, and yet she is to go with the tide: They set the fore-sail, fore top-sail, and mizen-sail, and let the ship drive with the tide, so that they may flat her about: And if she happen to come too near the shoar, then having a small anchor in the head of the boat, with a small hawser fastned to it from the ship, they let it drop in the middle of the stream; and this will *wend*, or turn her head about; when she is come fully about, they heave up the anchor again. This sort of working is called to *kedge*, or *kedging*; and the anchor thus used is called a *kedger*.

KEEL, is the first or lowest piece of timber in a ship; it lies in the very bottom of her hull, one end whereof is at the stern, the other at the stem; and into this, are all the ground timbers and hooks fasten'd and bolted fore and aft.

False keel, is a keel put on under the first, in case the ship be shallow, and so over-floaty, and roll too much.

L

LARBOARD, is the left-hand-side of the ship, when you stand with your face towards the head.

LARGE; a ship goes large, that is, she goes neither before the wind nor upon the wind; but, as it were, *quartering* between both, with a fresh gale, and all sails drawing.

To sail with a large wind, that is, with a fair wind.

L E E. This word is variously used ; but generally signifies the part opposite to the wind ; as the *lee shoar* is the shoar against which the wind blows ; but to be under the *lee* of the *shoar*, is to be close under the weather shoar, that is, the shoar whence the wind doth come.

Lee-hatch : *Have a care of the lee-hatch* ; that is, take care the ship does not go to the leeward of her course.

A lee the helm ; that is, put the helm to the leeward side of the ship.

To lie by the lee ; or *to come up by the lee* ; is to bring the ship so, that all her sails may lie flat against her masts and shrouds, and that the wind may come right upon her broad-side.

L O G, is a little piece of wood of a triangular form, with as much lead in one end thereof, as will serve to make it swim upright in the water, at the other end it is made fast to the *log-line*.

Log-line, is a small line, having the *log* fastned to one end ; and is wound upon a reel. The *log-line* for about 10 fathom in small ships, or more in great ones from the *log*, has or ought to have no knots or divisions, because so much should be allowed, that the *log* may be out of the eddy of the ship's wake, before the glass be turned up : Then the knots begin, and ought to be at least 50 feet asunder ; though the common practice at sea is to have them but 7 fathoms, or 42 feet distance. The use of the *log* and *log-line*, is to make an estimate of the ship's way, or distance run, by heaving it every hour, or every two hours.

To heave the log, is first to throw it into the water, and let it run away so far, as to be out of the eddy of the ship's wake; then one having a half-minute glass ready in his hand, turns it up just when the first knot runs off the reel; and so the line running easily off as the ship moves, when the glass is out, he cries *stop*, and the other stops the reel: Then counting the knots run out with the odd fathoms or feet (if any) they reckon, for as many knots as run out in half a minute of time, so many miles the ship sails in an hour; and for every 5 odd feet, a tenth part of a mile more. Thus three knots in half a minute, is three miles an hour; and four knots 25 feet in half a minute, is four miles and a half an hour.

The common division of the *log-line*, is grounded upon this supposition; that a mile contains 5000 feet, and 60 of such miles a degree; whence a degree would contain 300000 feet. Now half a minute being the 120th part of an hour, and the 120th part of 5000 feet being 41,6, &c. or near 42 feet, therefore as many times 42 feet as the ship runs in half a minute, so many miles she goes in an hour. So that according to this supposition, 42 feet must be the distance between the knots upon the *log-line*. But this supposition, and consequently the practice from it, is certainly erroneous; for a degree is now found to contain 360000 feet at least; therefore a minute or a mile must contain 6000 feet (which is the true sea mile) and since half a minute is the 120th part of an hour, the 120th part of 6000 feet is 50 feet, consequently as many times 50 feet as the ship runs in half a minute, so many miles she makes in an hour (supposing her to hold her pace) therefore the distance between knot and knot should be 50 feet.

LOOF,

LOOF, or *Loof* of a ship, is that part of her aloft, which lies just before the cheffe-trees.

Loof or *Luff*, is also a word used in condng a ship : As,

Luff, keep your *Luff*, that is, keep the ship near the wind.

Luff up, that is, keep nearer the wind.

To luff into a harbour ; is to sail into it close by the wind.

To spring the luff, is when a ship that before was going large before the wind, is brought close by the wind.

Loxodromick-line, is the line of the ship's way when she sails upon a rhumb oblique to the meridian.

LYE *under the sea* ; is said of a ship when her helm is lath'd fast a-lee, and she lies so a-hull, that the sea breaks upon her bow, or broad side.

M

MOOR ; to *moor* a ship, is to lay out her anchors so as is most convenient for her safe and secure riding. A ship is not said to be *moor'd*, unless she has at least two anchors out.

P

POINT *of the compass*, is the 32d part of the circumference of the circle on the card, or 11 degrees 15 minutes ; therefore *half a point* is 5 degrees 37 minutes ; *quarter point* is 2 degrees 48 minutes.

POOP *of a ship*, is the highest, or uppermost part of her hull a-stern.

PORT,

PORT, or *port the helm*, is a word of command to him at the helm, to put it to larboard, which will make the ship go to starboard.

The ship heels a port, that is, leans to the left.

Ports, are those holes in a ships side, through which the great guns are put out.

QUARTER of a ship, is that part of the ship's hull which lies from the steerage-room to the transom.

QUARTERING; *the ship goes quartering*, that is, she goes upon a quarter-wind; or she goes neither by a wind, nor before the wind, but betwixt both.

Quarter-wind, is when the wind comes in abaft, the main-mast shrouds, even with the quarter.

R

RAKE of a ship, is so much of her hull as hangs over both ends of her keel.

Fore-rake, or *rake-forward*, is that part of it which is before, and is usually more than a third, but less than half the length of the keel. A long *rake* forward gives the ship a good way; but then if she has not a full bow, it will make her apt to pitch much a head into the sea; besides, is a great charge and stress to a ship; because she hangs over so a head. But when a ship has a small *rake* forward, she becomes so bluff-headed, that the sea beating continually upon her bow, she cannot cut the water so readily as she ought, and consequently will make but small way.

Rake-aft, or *rake-aftward*, is that part which is at the setting on of the stern-post, and is generally

rally about a fourth or a fifth part of her *fore-rake*.

Rake of the rudder, is the aft-most part of the rudder.

REEVE ; is to draw a rope through a block to run up and down.

RIDE ; a ship is said to *ride*, when her anchors hold her fast, so that she drives not by the force of the wind or tide. And a ship is said to

Ride well, when she is built so, that she does not over-beat her-self into a head-sea, so that the waves do not over-rake her, that is, over-wash her from stem to stern.

Ride a-thwart, is to ride with her side to the tide ; and then she never strains her cable.

Ride betwixt wind and tide, is to ride so that the wind has equal force over her one way, and the tide the other ; which makes a ship roll and tumble very much, yet not strain her cables much.

Ride hawsful, or *to ride a stress* ; that is, when in a stress of weather, the ship falls deep into the sea with her head, so that the water runs in at her hawses.

ROAD, is any place near the land, where ships may ride at anchor.

RUDDER of a ship, is a piece of timber which hangs at the stern-post, having four, five, or six irons, call'd *pintles*, according to the bigness of the ship, which pintles are fitted to the gudgeons at the stern-post: this *rudder* is, as it were, the bridle which governs the ship ; the narrower the *rudder* the better, if the ship do feel it, for a broad *rudder*, as it holds much water, too much stops a ship's way, when put over to either side ;
but

but if the ship have a fat quarter, so that the water cannot come quick and strong to the rudder, then she will require a broad rudder. The putting to of the rudder, is term'd *the hanging of the rudder*. The part or edge next the stern-post, is call'd *the inside of the rudder*; the aftermost part, is call'd *the rake of the rudder*.

The rudder rope, is a rope reev'd thro' a hole in the rudder near the head, and likewise through the stern post, both ends being splic'd together. Its use is, to save the rudder, if by any accident it chance to be unhung.

RUMB, *Rhumb*, or course of a ship, is the angle which she makes in her sailing with the meridian of the place where she is. See **COURSE**.

Complement of the rumb, is the angle made by the line of the ship's way, with any parallel to the equator.

Rumb signifies also one point of the mariners compass, or the 32d part of the card, or horizon, that is, 11 degrees 15 minutes.

Rumb-line, is the line that is describ'd by the ship's motion, on the surface of the sea, steer'd by the compass, making equal angles with every meridian. These *rumb lines* are helispherical, or spiral lines, proceeding from the point set out from, winding about the globe of the earth, and after infinite revolutions come to the pole, where they end. See **LOXODROMICK-LINE**.

In plain and *Mercator's* sailing, these rumb lines are represented by strait lines. Their use is, to shew the bearing of any two places one from another; that is, upon what point of the compass any place lies from another.

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RUN of a ship, is that part of her hull under water, which comes narrower by degrees from the floor-timbers to the stern-post. This is also call'd the ship's way *ast-ward*; and according to the ship's run, she steers well or ill, by reason of the easiness or difficulty of the water's passage to the rudder. If too short, and too full below, the water comes but slowly to the rudder, because the force of it is broke by her breadth. This is sometimes remedied by putting on a false stern-post, tho' it is better to lengthen her.

Good-run; a ship is said to have a *good run*, when she comes off handsomely by degrees, and her tuck not lying too low.

Bad-run, when the tuck of a ship lies too low, it hinders the passage of the water to the rudder, and therefore she cannot steer well, nor keep a good wind, nor make any good way thro' the sea; but will be still falling to leeward.

S.

SEEL signifies much the same as *heel*; for as it is called *heeling*, when a ship lies down constantly or steadily on one side; so it is called *seeling*, when she tumbles on one side violently and suddenly, by reason of the sea's forsaking her, that is, the waves leaving her for a time in a rolling sea.

Lee seel; that is, when the ship tumbles to *Lee-ward*. In this, even in a storm, there is not much danger, for the sea will presently right her up again: But in case a ship *seels*, or rolls to *windward*, then there is fear of her coming over too short or suddenly, and so in danger of being foundered, by the sea's breaking right into her; or at least having some of her upper-works carried away.

SET;

S E T ; to observe on what point of the compass the sun, a ship, or any head-land bears, is call'd *setting the sun, land, &c.*

S H E E R ; that is, to swing too and again.

The ship-sheers ; that is, goes in and out, and not right forward, either by not steering steadily, or by means of the swift running of the tide, &c. In such case, they say, *she sheers, or goes sheering.*

S H E A T S, are ropes bent to the clew of the sails ; serving in the lower sails, to hale aft, or round off the clew of the sails ; but in top-sails, their use is to hale home, that is, to bring the clew of the sail close to the yard arm.

Standing part of the sheat, is that part of it which is made fast to the ring of the ship's quarter.

Over hale the sheat ; that is, hale upon the standing part of the sheat.

To hale aft the main sheats, is in order to make the ship keep by a wind.

To hale aft the fore sheats, is that the ship may fall off from the wind.

Ease the sheat ; that is, veer it, or let it go out gently.

Let fly the sheat ; that is, let it go all at once, and run out as fast as it can ; then the sail will hang loose, and hold no wind.

Tally the sheats ; that is, hale aft the sheats of the main and fore sail.

Flown sheats. A ship is said to sail with *flown sheats*, when her sails are not haled home, or close to the blocks.

The sheats are flown ; that is, they are let loose, or to run as far as they will.

False

False sheat, is a rope bent to the clews of the main and fore-sail, above the sheat block, to succour and ease the sheat in a violent gust of wind.

To SHIVER or *Shake* a sail, is to bring the yard in a line with the wind.

SHOT of a cable, is the splicing of two cables together, that a ship may ride safe in deep waters and great roads: For a ship will ride easier by one shot of a cable, than by three short cables out a head.

To SOUND, or *sounding*, is to try the depth of water by a line and plummet, called a

Sounding-line; that is, a line by which seamen find where the ship may sail by the depth of the water. It is generally about 20 fathom in length, and mark'd at two fathom next the lead, with a piece of black leather; at three fathom the like, but slit; at five fathom with a piece of white cloth; at seven fathom with a piece of red, &c. with some such distinction all along. This line may be used when the ship is under sail; which cannot be done so well with the *deep sea-line*, in using of which the ship is usually brought upon the back-stays.

SPOOMING, or *Spooning*; when a ship being under sail in a storm at sea cannot bear it, but is forc'd to put right before the wind, without any sail; then they say, the ship *spooms*: So that if a ship will neither *try*, nor *hull*, then they *spoon*; that is, put her right before the wind.

Spooning with the fore-sail; that is, when in spooning there is danger that the ship may bring her masts by the board with her rolling, or feel under

under water, and so founder ; then it is usual to set up the fore-sail, to make her go the steadier, especially if there be sea-room enough.

STARBOARD, is the right side of the ship, or the right hand ; as larboard-side is the left.

Starboard the helm, or *helm a starboard*, in conducting a ship, is to put the helm to the right side of the ship, or to put the helm a-starboard, to make the ship go to the larboard ; for the ship always sails contrary to the helm.

STAYING a ship, or to bring a ship upon the stays, is in order to her tacking ; and is done thus,

At the same time, *bear up the helm*, let fly the fore-sheut, let go the forebowline, brace the weather-brace of the fore-sail. The same is also done to the top-sail and top-gallant-sail, only their sheats must be kept fast. If the sprit-sail be out, then let go the sprit-sail sheat, with the fore-sheut, and brace the weather-brace.

But the tacks, sheats, bracings, and bowlines of the main-sail, main-top-sail and mizen, are not altered.

And when the wind comes in at the bow, which before was the lee-bow, it drives all the sails backwards against the shrowds and masts ; so that the ship makes no way forward, but drives with her broad side. Those are accounted the best ships, which will stay with the fewest sails.

STEER. To steer a ship, is to guide or direct her course by the helm. There are three kinds of direction to steer by, viz.

1. By any mark on the land, so as to keep the ship even by it.

2.

2. By the *compass* ; which is to keep the ship's head upon such a rumb, or point of the compass, as best leads to the design'd port.

3. To *steer* as one is bidden, or conn'd ; which is the duty (in great ships) of him that is taking his turn at the helm : And he is reckon'd the best *steers-man*, that uses the least motion in putting the helm over to and again, and that keeps the ship best from making *yaws*, that is, from running in and out.

STEERAGE, is that part of the ship next below the quarter-deck, before the bulk-head of the great cabin : 'Tis here, in most ships of war, stands the *steers-man*, or he that guides the helm or rudder of the ship.

STEM of a ship, is that great timber, which comes compassing from the keel (wherein it is skarfed) up before the fore-castle. This *stem* guides the rake of the ship ; and all the butt-ends of the planks forwards are fixed into it.

False-stem, is fixed before the right one, when that is made too flat for the ship to keep the wind well ; which defect is remedied by a *false-stem*, that will make her rid more way, and bear a better sail.

STEP of the mast, or capstan, in a ship, is that piece of timber whereon the mast or capstan stands at bottom.

STERN of a ship, is properly the outmost part of a ship abaft ; though generally speaking, it is all the hindermost or aftmost part of a ship.

Stern-

Stern-post, is a great timber let into the keel, at the stern of the ship, somewhat sloping, into which are fasten'd the after-planks ; and on this post hangs the rudder, by its pintles and gudgeons.

T

TACK, is a great rope with a whale knot at one end, which seiz'd into the clew of the sail, is reev'd through the ches-trees, and then is brought through a hole in the ship's side. It serves to carry forward the clew of the sail, to make it stand close by a wind ; the *tacks* of a ship are usually belay'd to the bitts, or else there is a chevil or cleat on purpose to fasten them ; they belong only to the main-sail, foresail, and mizen. When the sails are to be trimmed, so as to stand close to a wind, the main, fore and mizen *tack* are brought close by the board, and over-haled as forward as they can be ; the bow-lines are so also on the weather-side, the lee-sheats are haled close aft ; as also the lee-braces of all the sails are likewise braced aft, and the top-sails are braced and govern'd as the sails to which they belong.

Hale aboard the tacks ; that is, bring the *tack* down close to the ches-trees.

Ease the tack ; that is, slacken it, or let it go, or run out.

Let rise the tack ; that is, let it go all out.

The ship sails, or stands close upon a tack ; that is, close by the wind.

To tack about, is to bring the ship's head about, so as to lie the contrary way ; which is perform'd thus : First make the ship stay ; and when she is stay'd, they say she is *pay'd* ; then *let rise and hale* ; that is, let the lee-tack rise, and hale aft the sheats and so trim all the sails by a wind as before ; for they

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they cast off that which was before the weather-bowline, and set up the other taught. And thus they do also by all sheats, braces and tacks, which a ship that is trimm'd by a wind must have.

TACKLES, are ropes running in three Parts, having a pennant with a block at one end, and a block with a hook at the other end.

TAUGHT, or *Taut*, signifies stiff or fast ; as *hale taught a rope*, that is, set it stiff or strait.

TILLER, the same with the helm of a ship : It is most properly used in a boat, where that which would be the helm of a ship, is call'd the *Tiller*, and serves for the same use.

TRANSOM, is a piece of timber that lies a-thwart the ship's stern, between the two fashion pieces, directly under the gun-room port ; and it lays out the breadth of the ship at the buttocks : As when a ship is built broad or narrow at her *transom*, she is said to have a broad or narrow buttock.

TRIM of a ship, is her best posture, proportion of ballast, and hanging of her masts, &c. for sailing.

To find the trim of a ship ; that is, to find the best way of making any ship sail swiftly, or how she will sail best : This is done either by trying her sailing with another ship, so many glasses trimm'd ahead, so many a-stern, and so many upon an even keel ; or else by easing of her masts and shrouds ; some ships sailing much better when slack, than when they are taught. But this depends very much upon experience and judgment, and the several trials

which the commander and other officers may make aboard.

TRIP ; as *the ship goes with her top-sails a-trip* ; that is, when she carries her top-sails hoisted up to the highest, when it blows not too hard, but a gentle or loom-gale, as it is called.

TRY ; as *the ship lies a-try under a main-sail, or main course* ; that is, when she has no other sails abroad ; the tacks haled close a-board, the bowlines set up, the sheaths haled close aft, and the helm tied down close by the board, and so she is let lie in the sea. But at this time if she be upon a wind, she usually makes her way good, near three points before the beam.

To try under a Mizzen ; this is done when it blows so hard, that they cannot maintain the main-sail ; that is, cannot bear the main-sail out ; and then if she lie close by the wind, she will make her way about two points before the beam.

But if she *try* under a main-sail and mizen, she will make her way good about four points before the beam.

If a ship will neither *try* nor *haul*, then *spoom* ; that is, put her right before the wind.

V

VEER ; as, *veer out a rope*, that is, let it go by hand, or let it run out of itself.

Veer, is also used in reference to the wind ; as *the wind veers* ; that is, when it changes often, and suddenly, or shifts from point to point.

VEERING, as *the ship goes veering* ; that is, she goes at large, neither by a wind, nor directly

rectly before it ; but between both ; which is also call'd *quartering*.

VIOL, a kind of hawser, made use of to purchase in the cable, when the main capstan cannot do it ; because the ground in which the anchor is fix'd, is too stiff ; or else the sea runs too high, so that they cannot weigh it. In which cases they take a hawser, and opening one end of it, they put therein nippers, of about eight fathoms from each other, wherewith they bind this hawser fast to the cable, and then bring it to the jear capstan, to heave upon it. And this will purchase far more than the main capstan can.

W.

WAKE of a ship, is the smooth water a-stern, when she is under sail. This shews the way she has gone in the sea, whereby the mariners judge what way she makes ; for if the *wake* be right a-stern, they conclude she makes her way right forwards ; but if the *wake* be to leeward a point or two, then they conclude she falls to leeward of her course.

The ship stays to the weather of her wake ; that is, when in her staying she is so quick, that she does not fall to leeward upon a tack ; but that when she is tacked, her *wake* is to the leeward ; then it is a sign that she feels her helm very well, and is quick of steerage.

WARPING, is to hale a ship up by a hawser, or any other rope, sufficient for that purpose, with an anchor bent to it. This is used when a wind is wanting to carry a ship into, or out of a harbour.

Warp,

Warp, so is the hawser, or rope used to hale the ship up, called.

W A Y of a ship; as, *To keep an account of the ship's way*, is one of the most necessary things in the practice of navigation; and the most approv'd method of doing this, is by the log and log-line. Which See.

Lee-way, or *leeward way*, is the angle made by the point steer'd upon, and the way of the ship; and since most ships are apt to fall a little to lee-ward of their course, it is necessary at all times in casting up the log-board, to allow something for the lee-way; as.

1. If the ship be upon a wind, allow one point for lee way.

2. If the wind blow hard, and cause one top-sail to be taken in, allow two points for lee-way,

3. If the wind blow so hard that both top-sails are taken in, and the sea run high, allow three points for lee-way.

4. If the fore-sail be furl'd, and she try under a main-sail and mizen, she will make her way four points before the beam.

5. If she try under a main-sail only, she will make her way near three points before the beam.

6. But if she try under a mizen only, she will make her way about two points before the beam.

7. If she lie a-hull, with all her sails furl'd, she will make her way one point before the beam.

Way astward on, or *forward on*; that is, the rake or run of a ship. Which see.

W E A T H E R; as, *To weather a point*; that is, to pass by it on the weather-side. *To weather a ship*; that is, to go to windward of her.

Weather

Weather-coyle ; that is, when a ship has her head brought about, so as to lie that way which her stern did before, without loosing of any sail, but only by bearing up the helm.

Weather-gage. See GAGE.

W H I P, or *Whip-staff*, is a strong staff fasten'd into the helm of small ships, for him that steers to hold in his hand, thereby to move the helm, and steer the ship.

W I N D, is defined to be the stream or current of the air, which blows from some one of the two and thirty points of the horizon, or compass.

Windward ; that is, nearer the rise of the wind.

To have the Wind of a ship ; that, to be to windward of her.

Touch the Wind ; that is, keep as close upon the wind as possible.

The wind's eye ; that is, directly against the wind.

W I N D L A S S, is an instrument in small ships, placed upon the deck, just abaft the fore-mast. 'Tis made of a piece of timber six or eight foot square, in form of an axel-tree, whose length is plac'd horizontally upon two pieces of wood at the ends thereof, and upon which it is turned about by the help of handspikes, put into holes made for that purpose. This instrument serves for weighing anchors, or hoisting of any weight in or out of the ship ; and will purchase much more than any capstan, and that without any danger to those that heave ; for if in heaving the *windlass* about, any of the handspikes should happen to break, the *windlass* would paul of its self.

Y

YARDS of a ship, are those long pieces of timber made somewhat tapering towards each end, and fitted each a-thwart its proper mast, with the sails made fast to them, so as to be hoisted up, or lower'd down, as occasion requires. They have their particular names from the masts they belong to.

Yard-arm, is that half of the yard on either side of the mast.

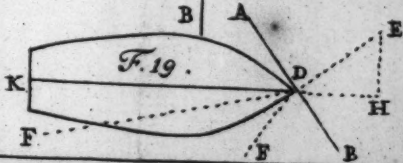
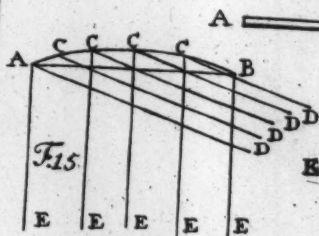
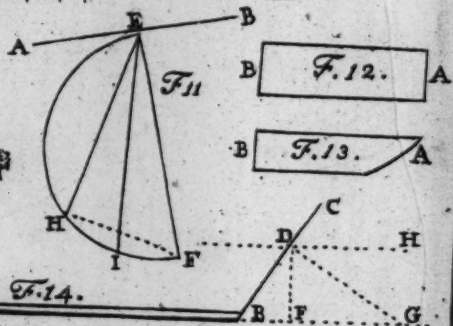
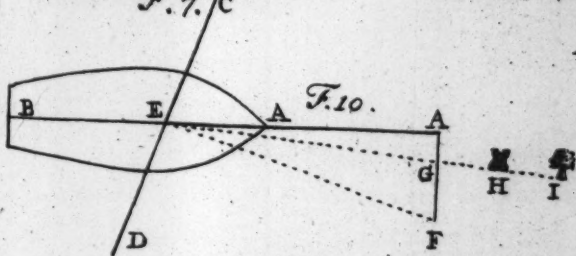
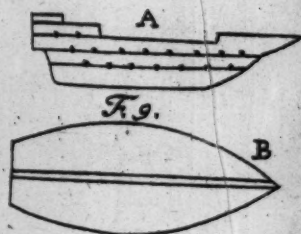
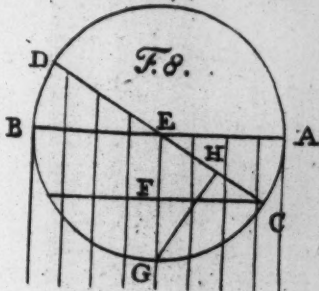
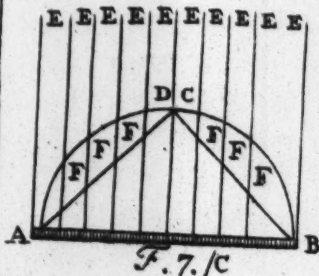
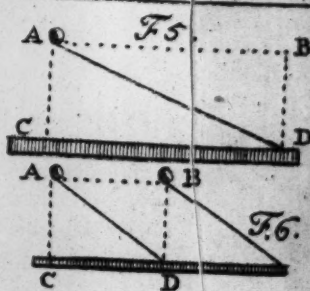
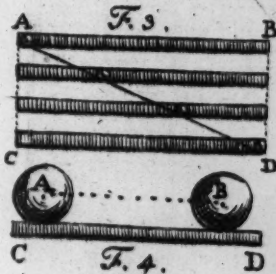
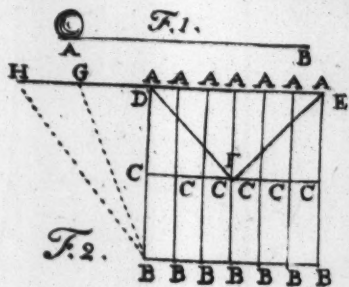
Brace the Yard; that is, traverse aft the yard-arm, whose brace is haled.

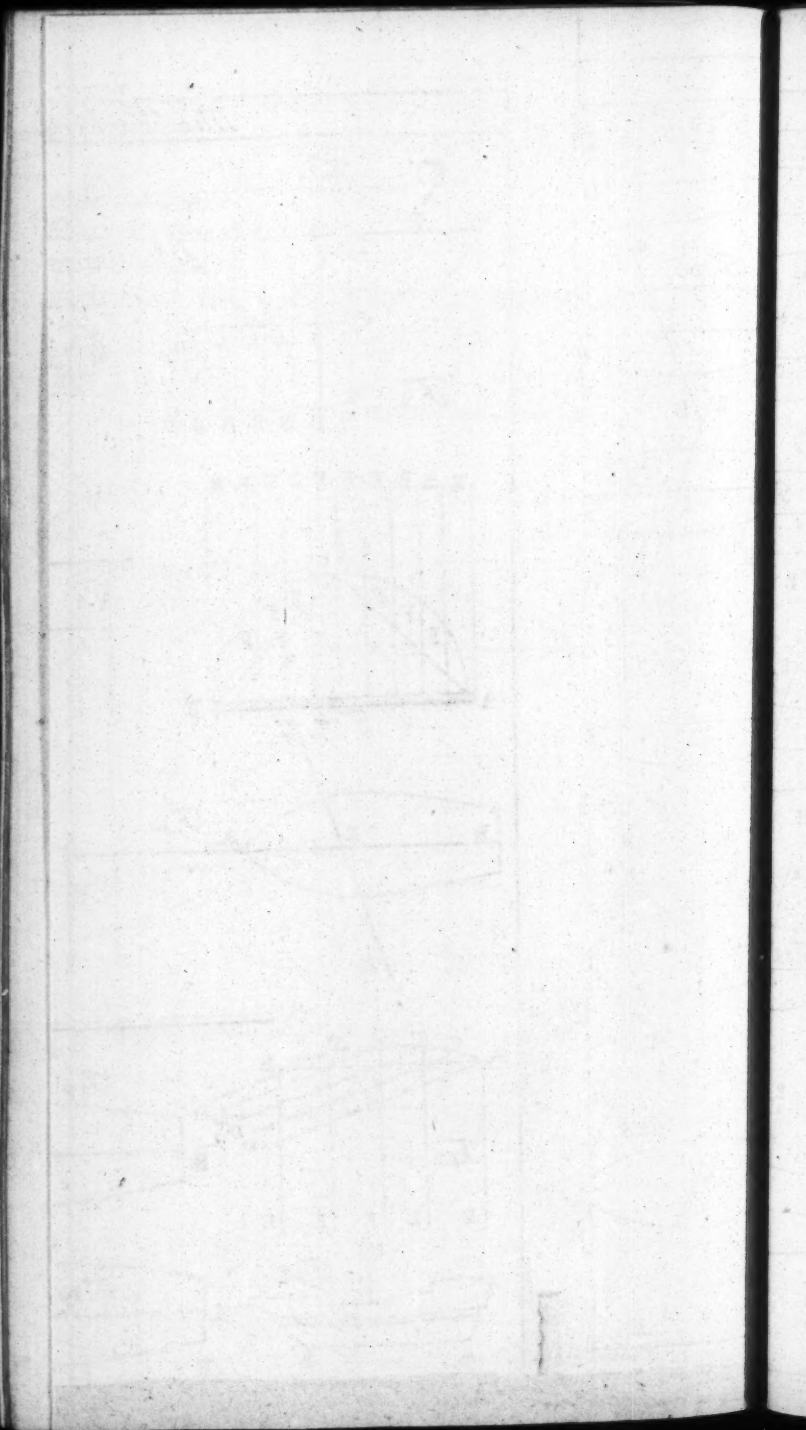
Square the yards; that is, see that they hang right a-cross the ship, and one yard-arm not traversed more than another.

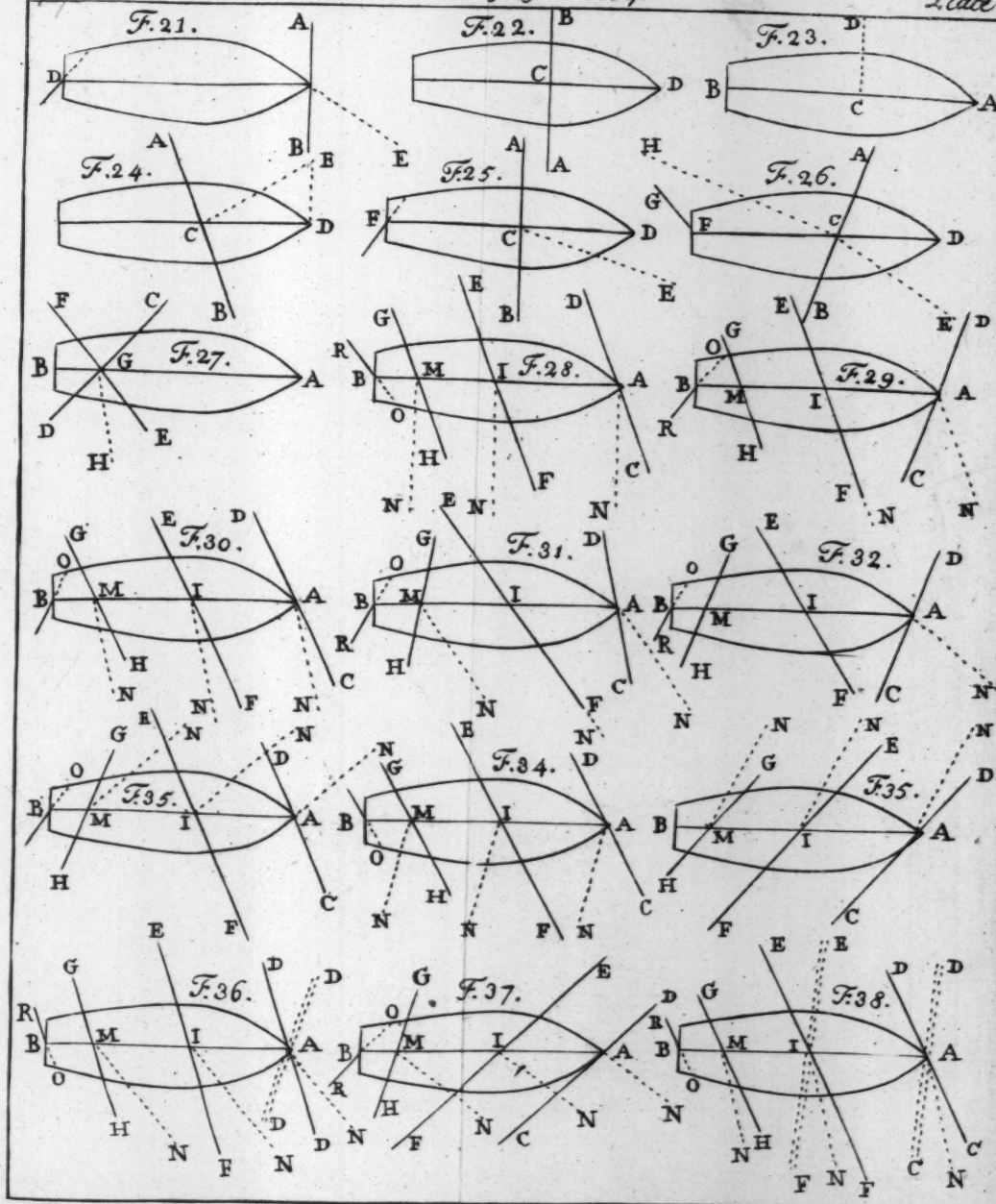
Top the Yards; that is, make the yards stand even; for to top the main and fore-yards, the clew-lines are the most proper; but when the top-sails are stow'd, then the top-sail sheats will top them.

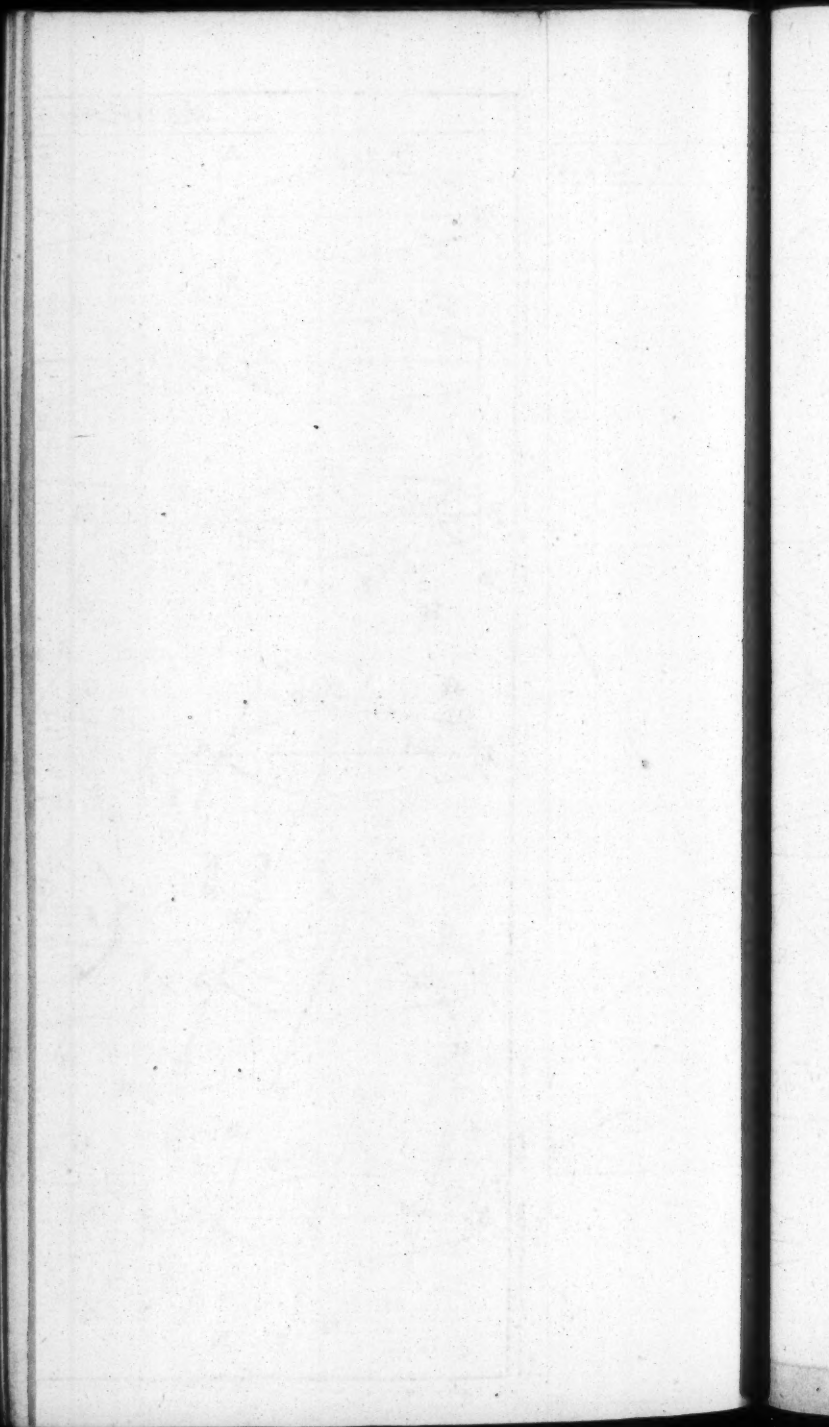
Y A W S; as *the ships makes yaws*; that is, does not steer steady, but goes in and out when there is a stiff gale. And he that keeps the ship most from yawing, does commonly use the least motion with the helm; and those steer best.

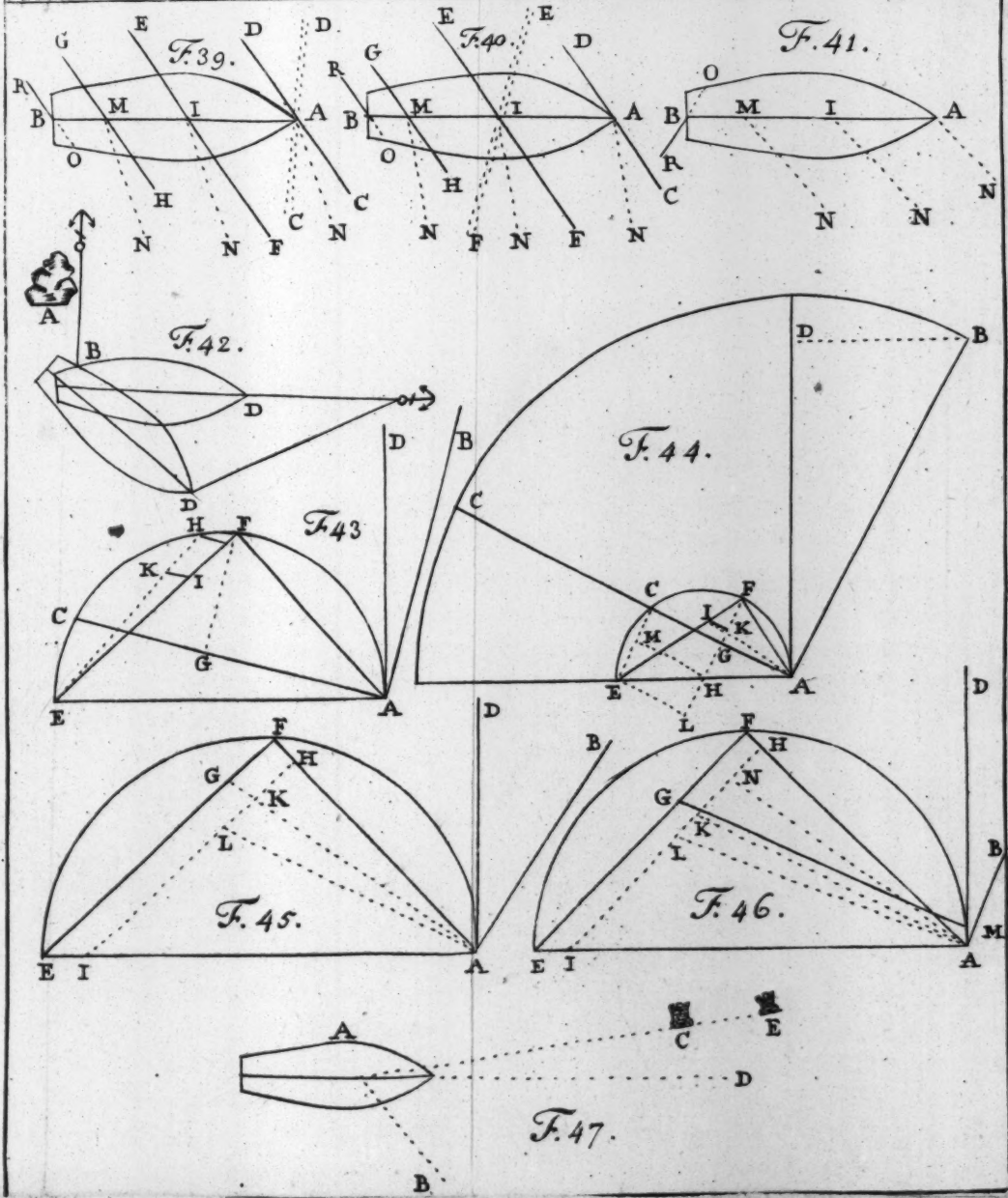


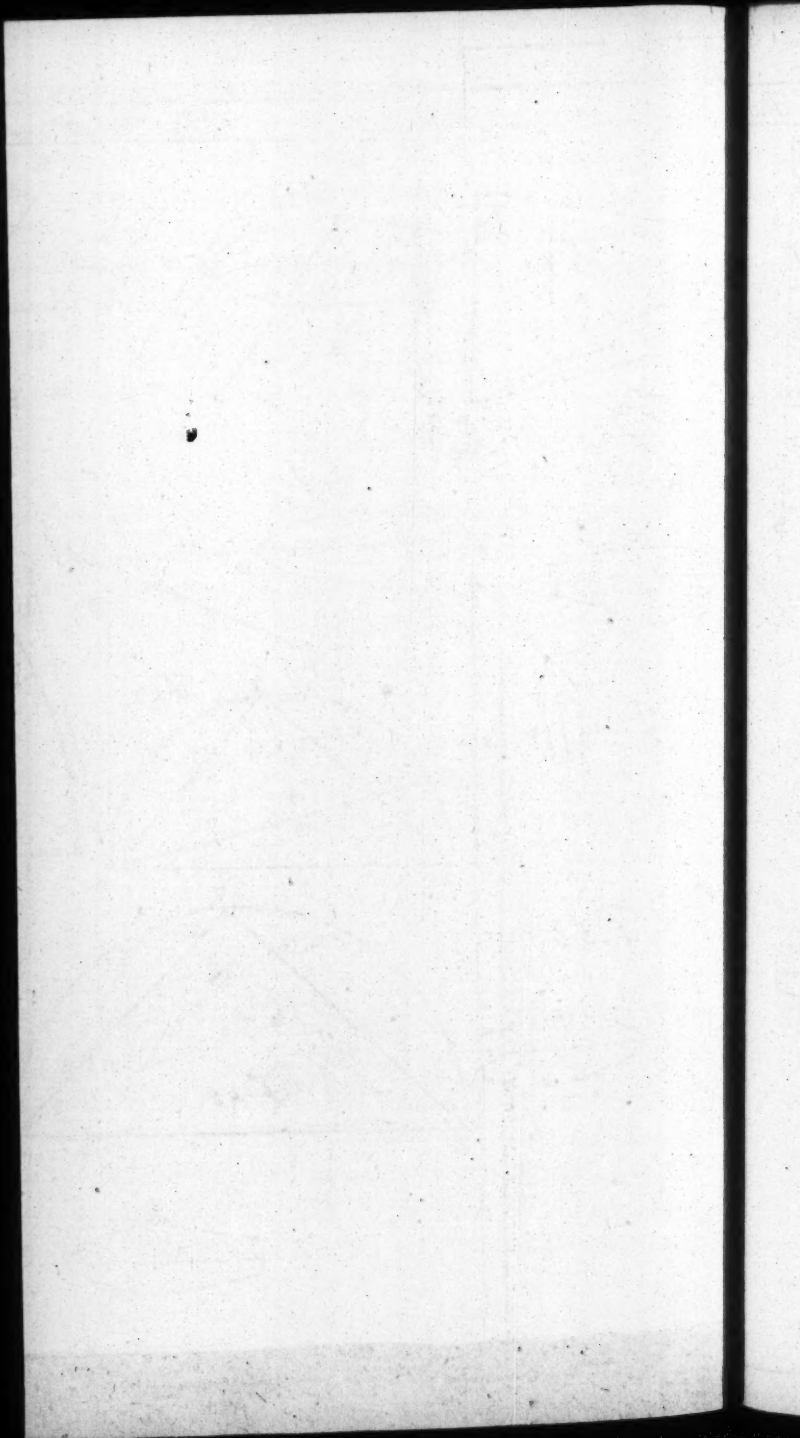


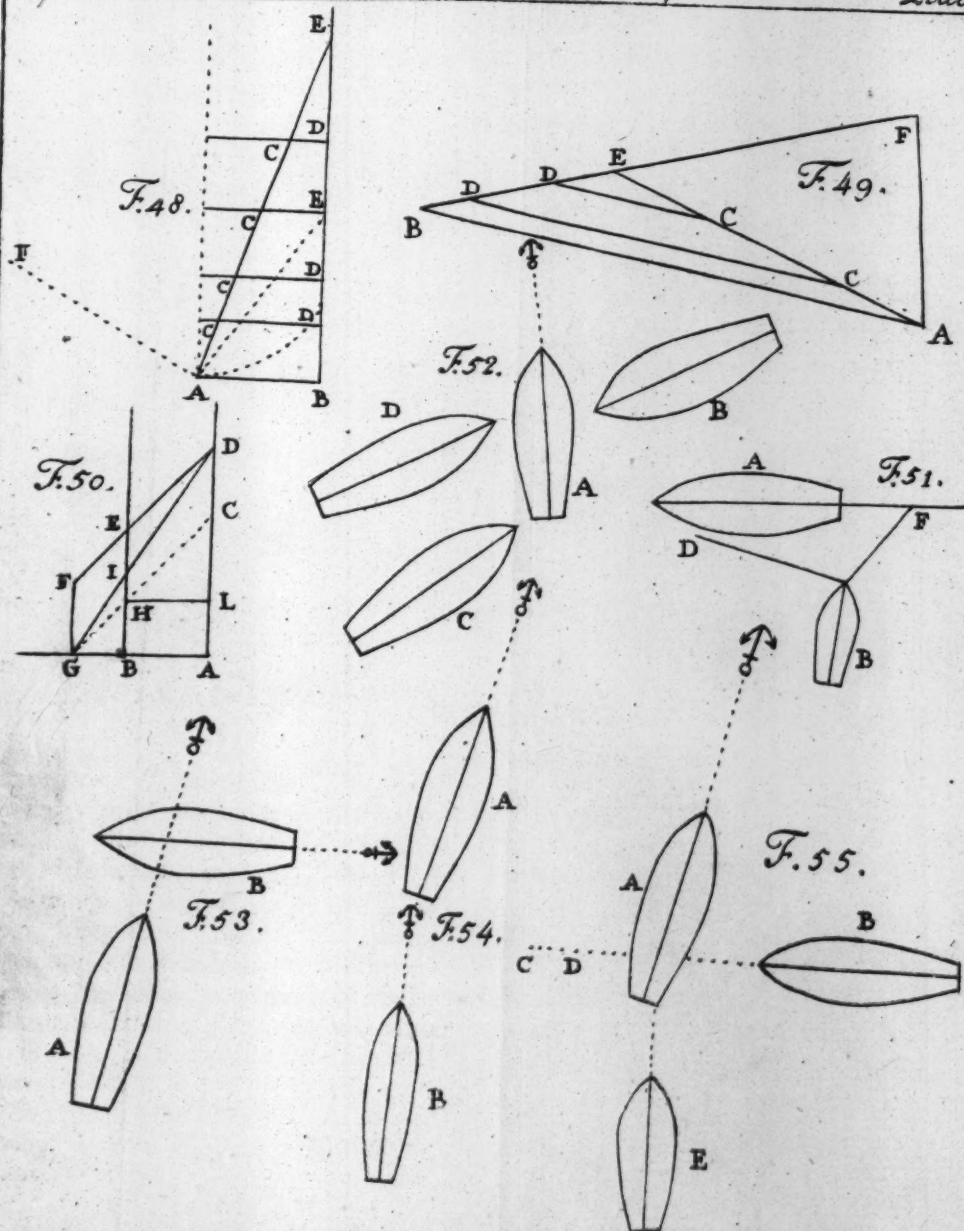


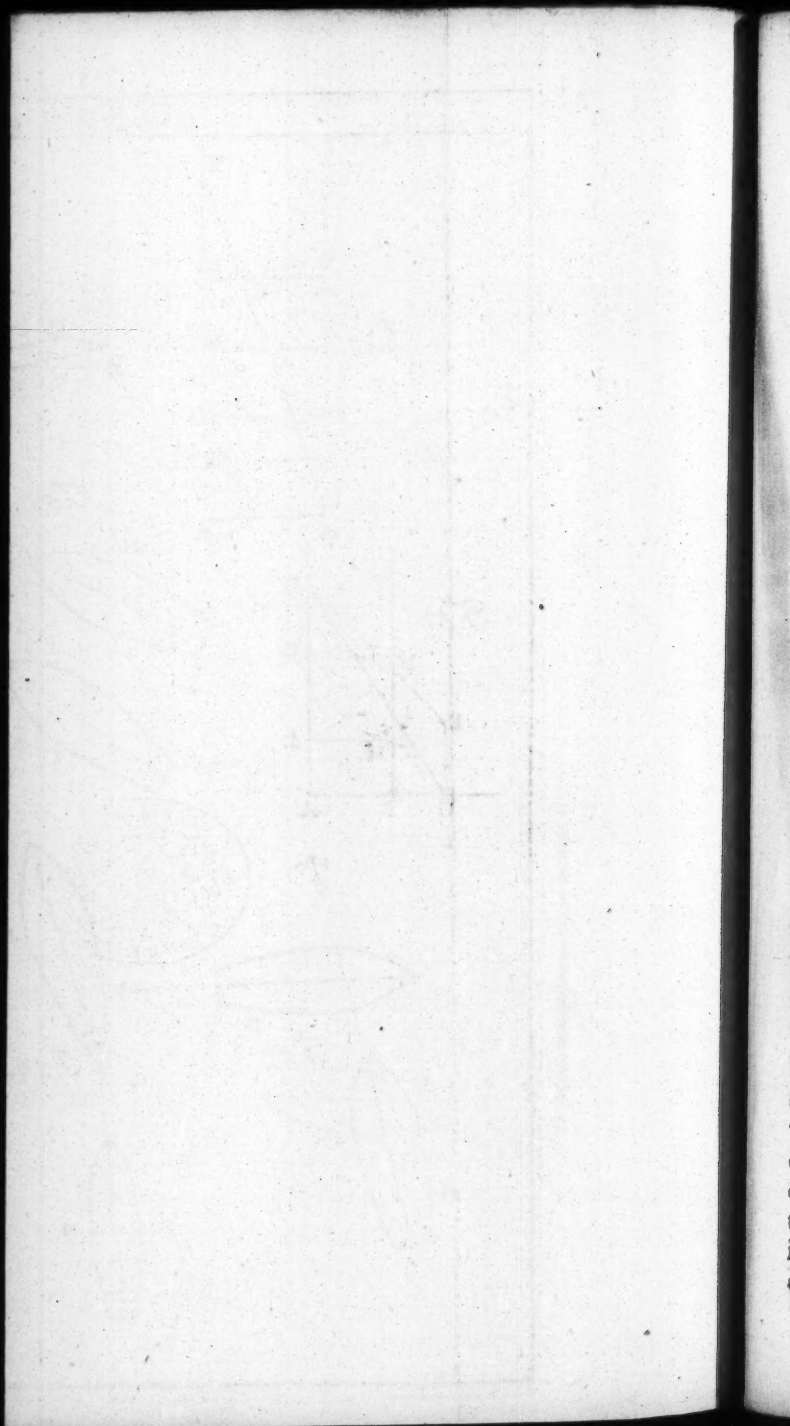














A N

A P P E N D I X,

Containing the

DESCRIPTION and Use

Of a Compleat

SET OF CASE OF POCKET-INSTRUMENTS.



COMPLEAT set of pocket-instruments (though sometimes made according to particular direction) generally consists of the following particulars, *viz.* 1. A large pair of compasses with one point made to take out, in order to receive in its place, either a drawing-pen, a port-crayon, or a dotting-wheel; according as you would describe your circles or arches, with ink, black lead, &c. or only with dots. 2. A smaller pair of compasses for the exact taking of distances, or striking obscure arches, &c. in working geometrical problems. 3. A longer drawing pen, whose handle contains a protracting

pin, and a socket to hold a pencil. 4. A parallel ruler. 5. A protractor, either semi-circular, or (as they are more commonly fitted up for cases) in form of a parallelogram or long square, for the conveniency of laying down on the back side thereof, several lines of equal parts, both simply and diagonally divided, with two or three lines of chords of different radii ; and sometimes all the several lines of the common plain scale are laid down thereon. 6. A sector. These cases of instruments are made of several sizes ; but most commonly either of the length of four inches, four inches and a half, or six inches ; which last size, though somewhat heavier for the pocket, are much more preferable in use, as the divisions upon the sector are more sensible, and consequently their application in practice more exact.

Of the Compasses.

A pair of compasses is a thing so well known, that it would be little less than ridiculous to waste words in its description ; but a few hints of direction in judging of their goodness, may probably be of service. Observe therefore, 1. That the motion of the head be equal, that is, that in opening or shutting you find no sudden jerks, or leapings. 2. That the joints are well fitted, so that there be no shake in the application of any of the points. 3. That they be well filed and polished. And, lastly, That the steel points are close join'd, equal and well tempered.

The use of a pair of compasses is as well known as their form ; I have therefore little to say under this head, but that it is an instrument well adapted

to the taking of distances, and describing circles, or arches from a given center; which, as before was intimated, may be done either obscurely, with the steel point; in ink, with the drawing pen point; in black lead, &c. with the crayon point; or by dots only, with the dotting wheel point; as the occasion requires. Note, also, either of these points may be used to draw a strait line along the edge of a ruler.

Of the longer drawing Pen, with the protracting Pin.

This instrument is composed of two steel blades fixed into a small pillar of brass, silver, &c. called the handle, one of which blades by means of a joint, may be made to open for the conveniency of cleaning, and by help of a little screw, they are easily set to the proper thickness of the line you would draw; the ink being inserted into the cavity betwixt the blades, with a common quill pen; so that if the blades are well fitted and polished, the line they draw will be exceeding smooth and even, which cannot be so certainly done with a common pen. The use therefore of this part of the instrument is only to draw streight lines, which generally should be drawn very fine. The other part, which is call'd a *protracting pin*, is a short piece of polished steel wire, fix'd in the lower end of the upper part of the handle, where it screws into the lower part to save the point, which is made very fine, from damage, when not used; its use is to set off angles from the protractor, as shall be hereafter shewn in describing that instrument.

Of the parallel Ruler.

This instrument consists of two equal rulers, so connected to each other, by moveable cross-pieces of brass or other metal, either fix'd parallel to each other, and lying assant when the two rulers are closed, or crossing each other with a joint in the middle, that to whatever degree the rulers are opened, they are still kept in a true parallel position to each other; by which means one part being set true upon any line, another line may be drawn by the other part of the ruler exactly parallel to that whereon the first is placed: Which expedient is of great use in delineating most sorts of draughts, particularly in plans of architecture, both military and civil; and in reducing a multangular figure to either a trapezitan or a triangle, for the more accurate and ready finding the content.

Of the Protractor.

The protractor is commonly a semi-
Fig. 1. circle, on whose chord or diameter is mark'd its center, and whose arch is divided into 180 equal parts, called degrees; being the half of 360, which every whole circle is supposed to be divided into (See fig. 1. at the end of the Appendix.) But for cases of instruments, it is frequently made in form of a parallelogram, upon three sides of which the same divisions are laid down from a center, mark'd on the fourth or diameter (as in the plate fronting the title, in the figure mark'd C.) Every 10 of these degrees are number'd, and every fifth distinguished with a longer mark than the others, for the greater ease in reckoning. They are

are usually number'd both ways, *viz.* from right to left, and from left to right, for the more readily laying down an angle from either end of a given line. The side to be applied to the paper is made flat, and that whereon the degrees are mark'd is filed so sloping, as to render the edges thin for the greater exactness in setting off, or measuring an angle; which are all the uses of this instrument as a protractor, and perform'd in the following manner.

1. If it was required to lay down an angle of 60 degrees, from the point A of *Fig. 2.* the line A B. Lay the diameter of the protractor on the line A B, so that the center may fall upon the point A, then with your protracting pin make a mark in your paper exactly against the number 60 upon the limb of your protractor; so shall a line drawn through the said mark to the point A, form an angle of 60 degrees.

2. If it be required to find the quantity of an angle given, as in the foregoing figure the angle B A C. Lay the diameter of the protractor on the line A B, so that the center may fall exactly upon the point A; then shall the degree on the limb cut by the line A C, shew the quantity of the angle, as before, 60 degrees.

On the reverse of a protractor, when made in form of a parallelogram (*Vide* figure mark'd D in the plate fronting the title) are usually laid down several scales, or lines of equal parts of different proportions, that is, of 45, 40, 35, 30, 25, and 20 parts to an inch, distinguish'd by the said numbers prefixed, and lines of chords of different radii;

radii ; besides these, there is another commonly called a diagonal scale, divided into quarters of an inch, with a half inch at one end, which half inch, and the extream quarter at the other, are both divided into ten equal Parts at their outward edges, and diagonal lines drawn from the beginning, first, second, &c. division at one edge of each to the first, second, third, &c. at the other, and the whole scale divided into ten equal parallel parts, whereby each of these extreams is divided into 100 equal parts ; and if this Scale be laid down within the vacant space on the face of the protractor (as in fig. C.) there may be room on the reverse (as in fig. D) for all the lines usually placed on the instrument, called the *plain scale*, as well as the before-mentioned lines of equal parts, &c. In giving therefore the construction and use of the plain scale, I shall sufficiently describe all the lines ever laid down on the reverse of a protractor, and shew their several uses and application in practice. But first I shall shew the use of these several scales or lines of equal parts, both as they are simply, and thus diagonally divided.

Of the Use of Scales, or Lines of equal Parts.

1. *Simply divided, Vide fig. D.* A line of equal parts is no more than a scale of measure in miniature, for laying down by way of plan, lengths taken by any known measures, as chains, yards, feet, &c. each part on the scale answering accordingly to one chain, one yard, or one foot, &c. The plan therefore will be the greater or less, as the scale used contains more or less parts in the space of an inch. Note, the first division on every scale is subdivided into 10 equal parts, which smaller divisions are the parts to be understood, when we

say

say it is a scale of 20 or 30, &c. If, therefore, these lesser divisions be taken as units, and each represent one league, one mile, one chain, one yard, or one foot, &c. the larger divisions will consequently be tens, tho' numbered with single figures; so that to set off 36 leagues, miles, chains, yards or feet, &c. extend the compasses from 3 of the larger divisions, to 6 reckoned backwards upon the smaller, and that extent laid down on your plan, shall accordingly represent 36 leagues, miles, chains, yards or feet, actually measured in the thing represented. To adapt these scales to foot measure, you will likewise find the first division of each duodecimally divided, above the decimal division, the halves and quarters of which are distinguished by longer marks than the rest, which are generally only dots; so that to lay down any number of feet and inches, as suppose 8 feet, 9 inches, extend the compasses from 8 of the larger divisions, to 9 of the upper small divisions; and the said extent laid down on your plan, shall represent by whatever scale it is taken, from 8 feet, 9 inches, in length actually measured. This may suffice for those scales which are only simply divided.

2. *Diagonally divided, Vide fig. C.* The first of these larger divisions of the half and quarter inch scales, being by the parallel and diagonal lines accurately divided into 100 equal parts, if the scale contains 7 or 12 of the larger divisions, any length to 700 or 1200 may thereby be more exactly taken off, than by those simply divided into 10 and 12 parts as above.

The projection of these diagonal scales is in this manner. First draw eleven parallel lines at equal distances, (*vide fig. C*) the whole length of which
I 5
being

being divided into a certain number of equal parts, according to the length of the scale, by perpendicular parallels; let the first division be again subdivided into ten equal parts, both above and below; then drawing the several oblique lines from the first perpendicular below, to the first sub-division above, and from the first sub-division below to the second sub-division above, &c. the whole first space shall thereby be exactly divided into 100 equal parts; for as each of the sub-divisions is one tenth part of the whole first space or division, so each parallel above it is one tenth of such sub-division, and consequently one hundredth part of the whole first space, and if there be 10 of the larger divisions, one thousandth part of the whole scale. If therefore the larger divisions be accounted as units, the first sub-divisions will be tenth parts of an unite, and the second sub-divisions mark'd by the diagonals, upon the parallels, hundredth parts of an unit; if the larger divisions be reckoned tens, the first sub-divisions will be units, and the second tenth parts: And if the larger divisions be accounted as hundreds, the first sub-divisions will be tens, and the second units. The numbers therefore 576, 57.6, 5.76 are all expressible by the same extent of the compasses, *viz.* setting one foot in number 5 of the larger divisions, extend the other along the sixth parallel, to the seventh diagonal: For if the 5 larger divisions are taken for 5 hundred, 7 of the first sub-divisions will be 70, which upon the sixth parallel, taking in 6 of the second sub-divisions, or 6 units, makes the whole number 576. Or, if the five larger divisions be taken for 5 tens or 50, seven of the first sub-divisions will be 7 units, and the 6 second subdivisions included upon the sixth parallel, will be six tenths of an unit. Lastly, if the

the 5 larger divisions be only esteemed as five units, then will the 7 first sub-divisions be seven tenths, and the 6 second sub-divisions six hundredth parts of an unit. And this I think may be sufficient to shew the use both of the simple and diagonal scales of equal parts: I now proceed to

The Construction and Use of the Plain Scale.

Having described the circle $A B C D$, and divided it into four quadrants, by the diameters $A B$ and $C D$, crossing each other at *Fig. 3.* right angles.

1. To project the line of *Tangents*. From the end C of the diameter $C D$, erect the perpendicular $C G$; then dividing the arch $C B$ into nine equal parts; from the center E , through the several divisions of the arch, draw lines till they cut the perpendicular $C G$, which will thereby become a line of tangents.

2. For the *Semi-tangents*. Lines drawn from the point D , through the same divisions upon the arch $C B$, will divide the radius $B E$, into a line of semi-tangents. For the semi-tangent of any arch, is but the tangent of half such arch; and by the 20th of the 3d of *Euclid*, it is prov'd, that an angle at the center, is the double of one at the circumference.

3. For the *Secants*. Since the lines drawn from the center through the several divisions of the quadrant $C B$, to form the tangents, are the secants of those respective arches, transfer those lengths to the line $E B$ continued to F , and the line $E F$ will be a line of secants.

4. For the *Sines*. From the several divisions of the arch CB, let fall perpendiculars upon the radius CE; so shall the radius CE be divided into a line of sines, which is to be numbered from E to C for the right sines, and from C to E for the versed sines. Note, the versed sines may be continued to 180 degrees, if the same divisions be transferr'd on the other side of the center E.

5. For the *Chords*. The arch CB being divided into 9 equal parts, in the points 10, 20, 30, &c. if therefore you imagine lines drawn from C, to the said several divisions, they will be the chords of their respective arches. Setting therefore one foot of your compasses in the point C, and transferring the several lengths C 10, C 20, C 30, &c. to the line CB, and the line CB shall thereby be made a line of chords.

Note, These several lines (which in the figure are drawn but to every 10 degrees) might be constructed to every single degree, if the circle were made large enough to admit of 90 distinct divisions in the arch of its quadrant.

6. A line of *Rhumbs* is thus constructed. Divide the arch DB into 8 equal parts, in the points 1, 2, 3, 4, &c. then setting one foot of the compasses in D, transfer the several distances D 1, D 2, D 3, &c. from the arch to the line DB, by which means you will form a line of rhumbs, each of which will answer to an angle of $11^{\circ} 15'$.

7. For the line of *Longitude*. Divide the radius EA into 60 equal parts (because 60 miles make

a degree of longitude under the equator) marking every ten with their proper number; from these divisions let fall perpendiculars upon the arch A D, then having drawn the line A D, with one foot of the compasses in A, transfer the several distances where the perpendiculars cut the arch, to the line A D; which shall thereby be made a line of longitude.

Now if the several lines with their respective divisions thus projected, in fig. 3. be transfer'd to the scale mark'd D, in the plate fronting the title, where they are distinguish'd by their proper names; and thereto be added lines of equal parts, as before describ'd, the instrument called the *Plain Scale*, will thereby be form'd.

But as upon the reverse of some protractors, besides the several lines already explain'd, there are two other lines laid down, *viz.* the line of latitude, and the line of hours; I shall likewise shew the manner how they are projected.

Projection of the Lines of Latitude, and of Hours.

1. To project the line of *Latitude*. In the same diagram (*viz.* fig. 3.) the radius C E being already divided into a line of sines, laying a ruler from the point B, through every of the said divisions, mark the points cut on the opposite arch A C, with the numbers 10, 20, 30, &c. then having drawn the right line A C, with one foot of your compasses in A, transfer the several intersections of the arch, to the said right line, which will thereby become a line of latitude, and may accordingly be laid down on your Scale.

2. To project the *Hour-Line*. Draw the tangent I K, equal and parallel to the diameter C D; and divide half the arch of each quadrant A C and A D, from the point A, into three equal parts, which will be 15 degrees each part, for the degrees of every hour from 12 to 6; each of which parts are to be again sub-divided into halves and quarters, &c. then drawing lines from the center of the circle, through each of these divisions and sub-divisions, till they cut the tangent line I K, the said tangent line will thereby be divided into a line of hours.

3. To these may be still added, another line, applicable to the same use, viz. the line of *Inclination of Meridians*, which is projected in the same manner as the hour-line; only divided into degrees, instead of time, every 15 degrees being equal to an hour.

The uses of the several lines thus laid down on the scale D, from the foregoing Projection, are as follow.

1. The *Tangents*, *Semi-tangents*, and *Secants*, serve to find the centers, and poles of projected circles, in the stereographical projection of the sphere, &c.

2. The *Sines* serve for the orthographical projection of the sphere, &c.

3. The line of *Chords*, serves either to set off an angle from a given point in any right line; or to measure the quantity of an angle already laid

laid down. The first is done by opening your compasses to the extent of 60 degrees upon the line of chords (which is always equal to the radius of the circle of projection) and setting one foot in the angular point, with that extent describing an arch; then taking the quantity of the angle required, between the feet of your compasses from the same chord-line, set it off from the given line upon the arch described; so shall a right line drawn from the given point, through the point mark'd on the arch, from the angle required. Thus to lay down from the point A of the line A B, an angle of 40 degrees, taking the extent of 60 degrees between the feet of your compasses from the line of chords, strike the arch C D, then setting off upon the said arch from D to C, the extent of 40 degrees taken from the said line of chords, from the point A draw the line A C, to pass thro' the point C, so shall the lines A B and A C form an angle of 40 degrees. The latter is done by describing as before, an arch with the extent of 60 degrees, and then taking the extent betwixt the lines which form the angle upon the said arch; that extent measur'd upon the same line of chords, will shew the quantity of the angle. *Fig. 4.*

4. The line of *Rhumbs* serves with more readiness than the line of chords, to lay down or measure the angle of a ship's course in navigation. For example, suppose a ship's course being N.N.E. it is required to lay down the angle.

Draw the line A B for the meridian, *Fig. 5.* then with 60 degrees of the chords, describe from the point A, the arch B C; and as N.N.E. is the second rhumb from the north, open your compasses to the second rhumb, and lay

lay off the extent upon the arch BC , so shall a right line from the point A through the point C , give the angle of the course BAC . Or if it were required to find the quantity of the angle of a ship's course BAC ; having described the arch BC , with 60 degrees of the chords, take the distance of the lines upon the said arch between the feet of your compasses, which measur'd upon the line of rhumbs, will shew the quantity of the angle.

5. The line of *Longitude*, being laid down on the scale contiguous with a line of chords of the same radius, number'd the contrary way, shews by inspection, how many miles there are in a degree of longitude, in each parallel of latitude; accounting the latitude upon the line of chords, and the miles of longitude upon the line of longitude. Thus in the latitude of 30 degrees, it appears that 52 miles makes a degree of longitude; in the latitude of 60 degrees, 30 miles make a degree; and in the latitude of 80 degrees, 10 miles make a degree, &c.

6. The two lines of *Latitudes* and *Hours*, are used conjointly, and serve very readily to mark the hour-lines in the construction of dials, on any kind of upright plains.

As an instance of which, I shall give one example of an horizontal dial for the latitude of *London*, viz. $51^{\circ} 32'$.

To construct an horizontal Dial, by the Lines of Latitude and Hours; for the Latitude of $51^{\circ} 32'$.

First,

First, draw the line E W of a convenient length, for the fix a clock line, and at right angles thereto, the line N S for *Fig. 6.* the meridian, or 12 a clock line, of a breadth equal to the thickness of the stile; the intersection of which lines, *viz.* the point A will be the center of your Dial: Then taking $51^{\circ} 32'$ (the latitude of the place) from the line of latitude, with one foot of your compasses in A, set off that extent on both sides, from A to E, and from A to W; then with the whole length of the line of hours between your compasses, set one foot in E, and cross the meridian line with the other; do the same on the other side from W, and draw the lines N E and N W, then taking between your compasses from the line of Hours, the distance from the beginning thereof to I, lay down that distance both ways from N to I, and from N to II, likewise from E to 5, and from W to 7; set off also the distance from the beginning of the line to II on the line of hours, both from N to 2 and 10, and from E to 4, and W to 8; and lastly, lay down the distance from the beginning of the line of hours to III, from N to 9, and from N to 3, which said distance will likewise reach from E to 3, and from W to 9. Thus having divided your trigon into its proper distances, lines drawn from the center A of the dial, through these several divisions, will mark the respective hour points on the limb of the dial, whether its figure be square or round; and for the hours before 6 in the morning, and after 6 at night, they are easily found by continuing the lines of the opposite hours through the center.

Note,

Note, The *file*, which is generally a thin plate of brass, must make an angle with the plain, equal to the latitude of the place; the angular point being fix'd just at the center A, and the *file* standing upon the meridian line, at right angles with the plain of the dial.

Of the Sector.

The *Sector* is a mathematical instrument, taking its name from a geometrical figure, which *Euclid* thus defines; a sector is a part of a circle, bounded by two radii, or semi-diameters, and part of the circumference, *viz.* the included arch. As an instrument, it consists of two equal legs, moveable about a joint like the common carpenter's rule; which being each of the length of 6 inches (though they may be made of any other determinate length, as in the figures mark'd A and B in the plate fronting the title, they are of 4 inches and a half) when quite open, they form an exact foot rule; and may be used as such in taking dimensions, being like other common rules, divided into inches and parts.

The lines commonly laid down on the faces of this instrument to be used sector-wise, are as follow, *viz.* upon one face (that mark'd A in the print.) 1. The lines of *Lines*, or length, consisting of equal parts. 2. The lines of *Chords*. 3. The lines of *Secants*. 4. The lines of *Polygons*. On the other face (marked B in the print.) 1. The lines of *Sines*. 2. The lines of *Tangents* to 45 degrees. 3. Other lines of *Tangents* to a lesser radius, to supply the defect of the former, from 45 degrees to about 75 degrees.

Note,

Note, If the lines of lesser tangents, and the lines of secants, be projected from a radius $\frac{1}{4}$ of the larger lines, and laid down upon the instrument to the same angle, then without any alteration in the opening of the legs, any extent taken on the lines of lesser tangents or secants, 4 times repeated, will give the proper tangent or secant, to the radius of the larger lines.

These several lines are projected and divided as the same lines upon the plain scale; but laid down upon the sector (all except the lines of polygons) so as that they may all make one certain angle, that is, to whatever degree the sector is opened, the distance will be the same betwixt 100 and 100 on the lines of lines, 90 and 90 on the lines of sines, 60 and 60 on the lines of chords, and 45 and 45 on the lines of tangents; and the angle each of these lines makes with its corresponding one, when the sector is quite shut, is easily seen, by the extent of the said distance taken from the center of the joint (called the center of the sector) laterally on either line of chords. The lines of lines are each divided into 100 equal parts, each of which are again sub-divided into halves and quarters, if the legs are of sufficient length; and with the lines of sines, chords and tangents, are each extended to the length of the radius of the circle from which they are projected; that is, the lines of sines to 90 degrees, the lines of chords to 60 degrees, and the lines of tangents to 45 degrees; each being number'd at every 10 degrees from the center to their several ends, where they are mark'd with the initial letters of their respective names.

Note,

Note, The correspondent parallels of the several lines are intended for the better distinguishing the several divisions upon each.

The lines of secants, and of lesser tangents, are each projected from a circle, whose radius is $\frac{1}{4}$ of that from which the other lines are projected; and beginning at the length of that radius from the center of the instrument, run to about 75 degrees. The tangents beginning at 45, where the larger lines of tangents end, have their degrees distinguished by the numbers 45, 50, 60, 70, 75, and the secants with the numbers 10, 20, 30, &c. to 75; and both are mark'd for distinction sake, with the small initial letters of their names.

The lines of polygons are laid down from the center of the joint, very near the inward edges of the instrument, and are numbered backwards from the ends towards the center, with the figures 4, 5, 6, &c. to 12, which comes within about three inches of the center.

These are all the lines which are usually laid down on this instrument to be used sectorwise.

The other lines which are placed upon, and parallel to the outward edges on both faces, and used as on common scales, the sector being quite opened, are, on the edge its self, a line of *Inches*, with each inch sub-divided into 10 equal parts; and on the faces, the line of *Numbers*, commonly called *Günter's Line*, with the lines of *Artificial Sines* and *Tangents*; also sometimes a line of *Hours*, with a line of *Chords*, and a line of *Latitudes*,

tudes, with a line of *Inclination of Meridians*, each being distinguished with its proper letter.

Of the Foundation and general Use of the Sector.

The foundation and general use of the sector depends upon the 4th proposition of the 6th book of *Euclid*, where it is prov'd, that the homologous sides of similar and equiangular triangles, are proportional to each other. Suppose therefore the lines AB , AC , to represent *Fig. 7.* any pair of lines upon the sector, particularly the lines of lines, making an angle BAC , with each other. If then, the line BC be drawn, and Aa , Ab taken equal, and the line ab also drawn; as Aa , or Ab is to AB , or AC , so will ab be to BC . Whence if the lines Aa , AB , be the half, the third, the fourth, &c. of the lines AB , AC ; the line ab will accordingly be the half, the third, the fourth, &c. of the line BC . As suppose AB , or AC be 100, and Aa , or Ab 50; then if BC be 60, ab shall be 30. Hence it follows, that if the lines AB , AC , represent the lines of chords, sines or tangents, that is, if the line AB , or AC be the radius, and the line Aa or Ab the chord, sine or tangent, of some proposed number of degrees to the said radius AB ; then the line ab will be the chord, sine or tangent of the same number of degrees to the radius BC .

And here note, that lines taken upon the sector, are distinguished by the terms *lateral* and *parallel*; those being call'd lateral, which are found upon the sides of the instrument, as $ABAC$; and parallel, are such extents as are taken from one leg to the other, at equal distances from the center of the joint, as BC , ab .

If therefore it be required to find the chord, sine or tangent of 20 degrees, to a radius of 5 inches; open the sector so that the distance from 60 to 60 on the lines of chords, may be equal to 5 inches; then will the parallel distance between 20 and 20 on the lines of chords, be the chord of 20 degrees, to a radius of 5 inches; so likewise the distance between 20 and 20 on the lines of sines, and between 20 and 20 on the lines of tangents, will be the respective sine or tangent of 20 degrees, to the said radius of 5 inches.

If a chord of more than 60 degrees be required to any assign'd radius; as suppose the chord of 80 degrees; open the sector as before directed to the radius given, and with the said radius, describe an arch sufficiently large, as AD; then

Fig. 8. taking the chord of half the number of degrees, *viz.* 40, lay it off twice upon the said arch, *viz.* from A to B, and from B to C, or which may be better, first lay off the radius from A to E, and then the chord of the excess, *viz.* of 20 degrees, from E to C, so shall a line drawn from A to C, be the required chord of 80 degrees.

If a tangent of more than 45 degrees be required, as suppose the tangent of 70 degrees, it must be taken from the lines of lesser tangents, which if not laid down to the same angle as the larger lines, as in most sectors they are not, then must the sector be so opened, that the distance between 45 and 45 on the said lesser tangents, may be equal to the given radius; so shall the distance between 70 and 70 upon the said lines of
lesser

lesser tangents, be the tangent of 70 degrees, to the radius given. But if the lines of lesser tangents are made (as they should be) to $\frac{1}{4}$ of the radius of the larger, and laid down to the same angle, then the tangent of any required number of degrees, either more or less than 45, may be taken off without any alteration in the opening of the sector; for in the instance above of 70 degrees, the distance between 70 and 70 on the line of lesser tangents, 4 times repeated, will be the tangent of 70 degrees, to the radius so set off between 45 and 45 on the line of larger tangents.

To find the secant of any propos'd number of degrees to a given radius, as suppose the secant of 60 degrees, to a radius of two inches; open the sector to the distance of 2 inches between 0 and 0 on the lines of secants; so shall the distance between 60 and 60 upon the said lines, be the secant of 60 degrees, to the radius of 2 inches: Or, if according to the above remark on the lesser tangents, the lines of secants are projected to $\frac{1}{4}$ of the larger radius, and form the common angle; the distance between any proposed point, 4 times repeated, will give the proper secant to the radius the larger lines are open'd to.

If the contrary of any of these operations be required, that is, if a given right line be the chord, sine, tangent or secant, of any certain number of degrees, as suppose 20, and the radius be sought; open the sector to the length of the given line, in the points 20 and 20 of the lines of chords, sines, tangents, or secants, according as the said line is either chord, sine, tangent or secant; and the distance between 60 and 60 on the chords,
between

between 90 and 90 on the sines, between 45 and 45 on the tangents, and between 0 and 0 on the secants, shall be the radius to the given line, whether it be chord, sine, tangent or secant.

This may suffice to shew the nature, general use, and excellence of this instrument; it evidently appearing from what has been said, that the *Sector* is, as it were, an universal *Plain Scale*, to any radius not greater than the extent of the instrument itself, when quite open, or less than the distance between the numbers at the ends of the respective lines, when quite shut.

And as the two lines of every pair make equal angles with each other respectively, they are thereby adapted to the working of proportions in equal parts and sines, equal parts and tangents, &c. so that among other things the several cases of Trigonometry may very readily be resolved by the sector. Some instances of which shall be hereafter given; but first I shall shew some particular uses of the lines of lines, and of the lines of polygons.

Of the particular Use of the Lines of Lines.

As lines of equal parts, their use is the same with such lines on common scales, serving to lay down any given length; but as they are laid down sectorwise, they have other various uses, some of the principal of which are shewn in the following problems.

P R O B L E M I.

To divide a given Line into any Number of equal Parts.

Take the extent of the given line between the feet of your compasses; then open the sector to make that extent be a parallel between the legs, in the points expressing the number of parts into which the line is to be divided; so shall the parallel distance between 1 and 1, divide the given line into the parts required. For example, suppose the line A B were given to be *Fig. 9.* divided into 6 equal parts; take the extent of the line A B, betwixt the feet of your compasses, and open the sector to make this extent be a parallel between the legs, in the points 6 and 6, and the parallel distance betwixt 1 and 1, *viz.* A C, shall be the $\frac{1}{6}$ part of the line A B.

If the given line be of too great extent to be applied to the legs of the sector, take one half, or one fourth of it, which being divided as above directed, into the parts required, the double, or quadruple of one of those parts, will accordingly divide the whole line into the number of parts proposed.

P R O B L E M II.

To divide a Line in the same manner as another is divided.

Lay down the divided line laterally on both sides of the sector, from the center, and mark the
K point

point of its extension; then opening the sector to the extent of the second line, in the terms of the first; apply likewise the several parts of the first line laterally on the legs of the sector, so shall the several parallels in the terms of those parts, be the correspondent parts in the line to be divided. Thus if the line CD were to be divided

in the manner as the line AB ; the
2 Figs. 10. extents of AB , AF , and AE , taken from the center laterally on both the lines of lines, which suppose on each line marked with B , F and E ; then open the sector to make the parallel BB equal to the line CD , so shall the parallels EE and FF , give the extent of CG and CH , in the line CD to be divided.

P R O B L E M III.

To find the Proportion between two, or more given Lines.

The proportion between any given lines may be measured upon either of the lines of lines, as on other scales of equal parts, without opening the instrument. But to perform the operation sectorwise, open the sector so that the extent between 100 and 100, may be equal to one of the given lines; then taking the other line, or lines, severally between your compasses, carry them with each extent along the legs of the sector, parallel to the former, till both points rest exactly on the same number in both the lines of lines, which number will give the proportion to 100, that each latter bears to the former. Thus if it were

Fig. 11. required to find the proportion between the lines AB and CD ; open the sector
to

to make the extent between 100 and 100 equal to AB ; apply the extent of the shorter line CD parallel to the former, and you will find the points to rest on 80 and 80; the proportion therefore of CD to AB , is as 80 to 100; or in smaller numbers as 4 to 5.

If the greater line AB , be too long to be applied between 100 and 100, cut off AE upon the greater line, equal to CD , and the sector being opened (as before directed) to make the extent between 100 and 100, equal the part AE ; then applying the extent of the part EB parallel to the former, you will find the points to rest on 24 and 24; so that the proportion of the part EB , to the part AE , will be found to be as 24 to 100; therefore the proportion of the line CD , to the line AB , will this way be found to be, as 100 to 124.

P R O B L E M IV.

To increase or diminish a Line in any given Proportion.

Open the sector to make the extent between the first proportional number, on both the lines of lines equal the given line; then the parallel distance between the other proportional number on the same lines, will be the line sought. Thus if the line A , is to be increased in the proportion of 3 to 7; open the sector to make the distance between 3 and 3, equal the length of the line A ; so shall the parallel distance betwixt 7 and 7, be the increased line B sought. On the contrary, if the line B was to be diminished in the proportion of 7 to 3; open the sector to

Fig. 12.

make the distance betwixt 7 and 7, equal the line B; then the parallel distance betwixt 3 and 3, shall be the diminished line A sought. Note, it may be sometimes more convenient to work with the equimultiples of the numbers given, which will produce the same effect; thus for the proportion of 3 to 7, you may take the numbers 6 to 14, 9 to 27, 12 to 28, or 30 to 70, &c.

P R O B L E M. V.

To find a third Proportional to two given Lines.

Lay down both the given lines laterally on the legs of the sector, observing the points of their extension; then taking the second line between your compasses, open the sector to its extent in the terms of the first line, so shall the parallel distance between the terms of the second line, be the third proportional sought. For example, let the two

given lines be A and B, which being
Fig. 13. laid down on the sides of the sector from the center A, suppose the terms of the first line to be BB, and the terms of the second CC; then opening the sector in the terms BB, to the extent of the second line B, the parallel distance between CC shall be the third proportional sought. For as A is to B, so is BB (equal to the line B) to CC.

P R O B L E M. VI.

To find a fourth Proportional to three Lines given.

Let the first and third lines, be both laid down laterally on the legs of the sector, from the center; then opening the sector in the terms of the first line,

line, to the extent of the second line; the parallel distance between the terms of the third line, shall be the fourth proportional. For example, let A, B and C, be the three lines given; set off A and C on the sides of the sector, from the center A, marking the terms of their extension BB, and CC; then taking the second line B, open the sector to its extent, in the terms of the first line A, viz. BB; and the parallel distance betwixt CC, the terms of the third line C, shall be the fourth proportional sought. *Fig. 14.*

Note, In Geometry, as well as in Arithmetick, it is not necessary, that all the proportionals be of one denomination; but only that the fourth found correspond with the second, as the third with the first; therefore the first and third proportionals may be measured by one scale, and the second and fourth by another; and to this end, a diagonal scale longer by an inch than the sector, when opened, whose grand divisions might be half-inches, with an inch at one end, and the half inch at the other, diagonally divided, would be better for use in the lateral extents, herein directed to be taken on the lines of lines, and a beam-compass for taking them off.

But a beam-compass scale divided into 30 and 40 parts in every inch throughout, and these again each sub-divided by *Nonius's* divisions into ten parts, (that is, each inch into 300 and 400 parts) on the index carrying the moveable point, which sets off any extent within its length, to the 800th part of an inch (or divided only into 20 parts in every inch; that may by two *Nonius's* divisions be again each sub-divided into 20 and 50 parts, whereby each inch

is divided into 400 and 1000 parts) is vastly to be preferred ; and as the points in these are perpendicular, and have no spring, nor are liable to alter from the extent, they are readily and most exactly set to, by the means of an adjusting screw ; is also on these accounts better than the other compasses, for determining the truer opening of the sector, and for taking the parallel extents thereon, and especially as with this beam-compass the given side or sides may be taken to answer nearly to the extreme opening of the sector, by doubling, trebling, halving, &c. if needful, whereby the solutions in plain trigonometry, &c. will be had much nearer truth, than when opened to a small angle.

P R O B L E M VII.

To find a right Line nearly equal to the circumference of a given Circle.

Since the proportion of the diameter of a circle to its circumference, is nearly as 3.183 to 10 ; therefore opening the sector to make the distance between 3.183 on both lines of lines, equal the length of the diameter of the circle proposed, the parallel distance between 10 and 10, will be the length of a line nearly equal to the circumference of the given circle.

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P R O B L E M VIII.

To open the Sector so that the two Lines of Lines (and consequently the others respectively, if they are laid down as they ought, at equal angles) may stand at right angles with each other.

Since by the 47th proposition of the 1st book of *Euclid*, it is demonstrated, that in a right-angled triangle, the square of the hypotenuse is equal to the sum of the squares of both the legs; therefore, if the whole lateral length of one of the lines of lines, taken as 10 equal parts, be set over from 8 on one leg to 6 on the other, the two lines of lines (and consequently the other pairs respectively) shall stand at right angles with each other; for 64 the square of 8, added to 36 the square of 6, makes 100, equal to the square of 10.

With the beam-compass and sector.

Open the sector to make each pair of lines become one strait line; then set the beam-compass to extend from 45 to 45 in the lines of sines, or from 70.71 to 70.71 in the lines of lines, and this extent made a parallel radius between the ends of either of the said pairs of lines, by moving them thereto, the two lines of every pair shall stand more truly at a right angle with each other.

To these few problems peculiar to the lines of lines, I shall add one or two of a more general nature.

P R O B L E M IX.

To open the Lines upon the Sector or the edges of the Instrument itself to any proposed Angle.

Take the quantity of the angle proposed, laterally from the center on one of the lines of chords; then open the sector to make this extent be a parallel betwixt 60 and 60 on the said lines, so shall the two lines of chords, and of every other pair of lines, stand respectively with each other at the proposed angle. Thus, to open the lines to an angle of 20 degrees, take from the center the lateral extent of 20 degrees on either line of chords; then open the sector to make this extent be a parallel betwixt 60 and 60 on the said lines; and the two lines of chords, and consequently all the other pairs, each being laid down to the same angle, shall accordingly form an angle of 20 degrees, each with the other respectively. And if (as in the print prefix'd to this work) in every pair of lines, each line forms with the other an angle of 6 degrees, when the sector is quite shut, it is but adding 6 degrees to the quantity of the angle proposed, in taking the lateral extent, and the parallel so made, as above, shall set the edges of the instrument itself to the angle required.

Note, If the angle proposed exceeds 60 degrees, open the sector to make each pair of lines become one strait line, and take with the beam-compass the parallel extent between the number of half the angle on each line of sines; then move the sector to make this extent a parallel radius between 90 and 90, at the ends of the said lines, and so shall the

two lines of every pair stand respectively with each other at the proposed angle: But if the angle proposed exceeds 120 degrees, the lines or the edges of the sector may be more truly set thereto by the protractor.

P R O B L E M X.

The Sector being opened, to find the quantity of the Angle, which either the several pairs of Lines, or the edges of the Instrument, make with each other.

This problem is but the reverse of the former: For if the parallel distance betwixt 60 and 60 on the line of chords, be applied laterally from the center on either of the said lines, the degrees of its extension is the measure of the angle that each of the several pairs of lines makes with its corresponding one; deducting therefore 6 degrees from the quantity so found, for the angle that each of the several pairs of lines makes with its corresponding one, when the instrument is quite shut, and the remainder will be the quantity of the angle formed by the edges of the instrument. But if the angle was greater than 60 degrees, the parallel radius, applied in the lines of sines, when the sector is opened to make the two one strait line, will give on both, at equal distance from the center, the degrees of half the angle the said lines had made with each other.

Of the Use of the Lines of Polygons.

The lines of polygons are chiefly contrived for the ready division of the circumference of a circle

into any number of equal parts from 4 to 12, that is, as a ready means to inscribe regular polygons of any given number of sides, from 4 to 12, within a given circle: To do which, set off the radius of the given circle (which is always the side of the inscribed hexagon) as a parallel betwixt 6 and 6, upon the said lines, so shall the parallel distance betwixt 5 and 5, be the side of a pentagon; between 7 and 7, the side of a heptagon; between 8 and 8, the side of an octagon, &c. All which is too plain to need an example.

N. B. All such regular polygons, whose number of sides (exceeding five) will exactly divide 360 (which the circumference of every circle is) without a remainder, may likewise be very readily set off upon the circumference of a circle, from the lines of chords; for opening the sector to make the extent of the radius of the circle, to be a parallel betwixt 60 and 60 on the lines of chords, and having divided 360 by the number of sides, the parallel distance betwixt the number of the quotient on the said lines, shall be the side of the polygon required; thus for an octagon, take the distance betwixt 45 and 45; and for a pentadecagon, the distance betwixt 24 and 24, &c.

If it be required to form a polygon upon a given right line; open the sector to make the extent of the given line, to be a parallel betwixt the points on the lines of polygons, answering to the number of sides, of which the polygon is to consist; as for a pentagon, betwixt 5 and 5; or for an octagon, betwixt 8 and 8; so shall the parallel distance betwixt 6 and 6, be the radius of a circle, whose circumference shall be divided by the given line, into the number of sides required.

The

The lines of polygons are likewise useful in describing upon any given line, an isosceles triangle, whose base angles shall each be double that at the vertex. For taking the given line betwixt your compasses, open the sector till that extent reaches from 10 on one leg, to 10 on the other; then shall the parallel distance betwixt 6 and 6, be the length of the two equal sides of the triangle sought.

Before we proceed to the manner of working proportions upon the sector, it will be necessary to consider the nature of the lines of artificial numbers, sines, and tangents; because as the same proportions may likewise be work'd upon these artificial lines, so one method of working, will serve as a proof of the other.

Of the Lines of Artificial Numbers, Sines and Tangents.

These several lines, which are usually laid down upon sectors parallel to the outward edges, in the same manner as upon other scales, are only the logarithms of the natural numbers, sines, and tangents, thus transferred to a scale.

1. The line of numbers, or *Gunter's line*, as it is commonly called, is a line of geometrical proportion, divided into 9 unequal parts, beginning at 1 towards the left hand, and number'd on with 2, 3, 4, 5, &c. to 9, next below 1 at the middle of the line; where another radius begins, and the same divisions are repeated, and number'd on (as before) to 9 with 10, at the end of the line on the right hand. Each of these primes, or first

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grand divisions, are sub-divided according to the same ratio, into 10 other parts, and each of these sub-divisions (if the line be of sufficient length) should again be sub-divided into 10 other lesser parts. But upon pocket-sectors, which when opened are but 12 inches in length, only the part from 1 in the middle, to 2 towards the right hand, is a second time divided, and that but into 5 parts instead of 10, every one of which must therefore be accounted as 2 centesms. In numbering therefore upon the line (wherein consists the greatest difficulty) the figures, 1, 2, 3, &c. which denote the primes, may be taken arbitrarily, either as units, tens, hundreds, or thousands; or they may represent the tenth, hundredth, or thousandth parts of an unit.

If 1 at the beginning of the line, be taken for unity, then 1 in the middle will be 10, and 10 at the end 100; but if the first 1 be accounted 10, then 1 in the middle will stand for 100, and 10 at the end for 1000; or, if the first 1 be reckon'd 100, then 1 in the middle will be 1000, and 10 at the end 10000; so that whatsoever value shall be put upon the first 1, the others will bear a like proportion.

When therefore the first 1 or prime, represents 10 units, the figures 2, 3, 4, &c. to 1 in the middle, will stand for 20, 30, 40, 50, 60, 70, 80, 90, 100, and each tenth, or sub-division in the first radius of the line, will signify 1 unit, and each centesim, or second sub-division (if there be any) will be $\frac{3}{10}$ parts of an unit; 1 in the middle will be (as before observed) 100, and the figures 2, 3, 4, &c. following 200, 300, 400, &c. each tenth,

tenth, or sub-division in the second radius, will denote 10 units, and each centesim 1 unit. Again, let the first 1 represent 100, then the figures 2, 3, 4, &c. will signify 200, 300, 400, &c. and 1 in the middle 1000, and 10 at the end 10000; according to this supposition, in the first radius, each tenth of a prime will be 10 units, and each centesim 1 unit; and in the second radius, each tenth of a prime 100, and each centesim 10.

In accounting decimal fractions upon the line; if 1 in the middle of the line be accounted as unity, then will each prime in the first radius denote 0,1, each tenth of a prime 0,01, and each centesim 0,001. If 10 at the end of the line to the right hand, be accounted as unity, the whole first radius will represent 0,1, and the numbers 2, 3, 4, &c. in the second radius 0,2, 0,3, 0,4, &c. and every prime in the first radius, and every tenth of a prime in the second radius, will signify 0,01, or one hundredth part of unity, and every tenth of a prime in the first radius, or centesim in the second, will denote 0,001, or one thousandth part of unity.

The numeration of the line thus explain'd, let it now be propos'd to find the point thereon answering to the number 436. For the 4 hundred, take the 4 first primes next the left hand; for the second figure 3, take 3 tenths of the grand division betwixt 4 and 5, and for the 6 units, reckon 6 centesims, or 6 parts of the next tenth; so that the extent from 1 at the beginning of the line, to that point, will express the number 436. The same point will likewise represent the numbers 43,6; 4,36; or 0,436; if the first 1 be accordingly accounted 10, 1, or $\frac{1}{10}$ of unity.

To

To multiply upon the line, extend your compasses from 1 at the beginning, to the point representing the number of your multiplier, the same extent will reach from the number of your multiplicand, to the product; thus, if 125 were given to be multiplied by 42; extend the compasses from 1 to 42, and the same extent will reach from 125 to 5250.

To divide upon the line; extend the compasses backwards from the number of the divisor, to unity; the same extent laid the same way, will reach from the number of the dividend to the quotient: Thus if 5250 were given to be divided by 125; extend the compasses backwards from 125 to unity, the same extent will reach the same way, from 5250 to 42.

2. The line of artificial sines, consists only of the logarithms of the natural sines, transferr'd from a table of logarithms to the scale; they are number'd from the left to the right, with the figures 1, 2, 3, &c. to 10, and so forward with 20, 30, 40, &c. to 90, at the end on the right. In the first part of the line, the grand divisions each represent one degree, so that if each prime be sub-divided into 12 parts (as they commonly are upon sectors) each sub-division will signify 5 minutes. In the latter part of the line, the grand divisions which are each 10 degrees, being sub-divided into 10 parts, each sub-division will represent 1 degree, and according as they are again sub-divided into 4, 3, or 2 parts, such second sub-divisions contain 15, 20, or 30 minutes each.

3. What has been said of the line of fines, is likewise to be understood of the line of artificial tangents, whose divisions begin at 1, and is number'd 2, 3, &c. on to 10, in like manner as the fines, signifying single degrees; and in the second part it runs on with 20, 30, &c. to 45, which stands at the end of the line, then these return back again to 89 where the line begins, as would be evident from the inspection of the line itself, if it was number'd backward, as it ought to be, and in some that are large really are.

The use of these lines is in working proportions, whether arithmetical or geometrical; particularly they are of very ready service in trigonometrical solutions.

The method of working with them is thus: In all proportions you have three terms given, to find a fourth. Seek out therefore the first term, whether number, sine, or tangent, in its proper line; and on that point set one foot of your compasses, extending the other to the second, or third term, which-ever of them is of the same name with the first; the same extent laid from the other term, the same way, will reach to the fourth term required.

Thus to work the following proportion; as the sine of $52^{\circ} 30'$ to the number 85, so is radius, or the sine of 90° , to the fourth number required. Set one foot of your compasses in the line of artificial fines on $52^{\circ} 30'$, and extend the other foot to 90° on that line, the same extent will reach from 85 on the line of numbers to 107, the fourth number required. And thus are all

To multiply upon the line, extend your compasses from 1 at the beginning, to the point representing the number of your multiplier, the same extent will reach from the number of your multiplicand, to the product; thus, if 125 were given to be multiplied by 42; extend the compasses from 1 to 42, and the same extent will reach from 125 to 5250.

To divide upon the line; extend the compasses backwards from the number of the divisor, to unity; the same extent laid the same way, will reach from the number of the dividend to the quotient: Thus if 5250 were given to be divided by 125; extend the compasses backwards from 125 to unity, the same extent will reach the same way, from 5250 to 42.

2. The line of artificial sines, consists only of the logarithms of the natural sines, transferr'd from a table of logarithms to the scale; they are number'd from the left to the right, with the figures 1, 2, 3, &c. to 10, and so forward with 20, 30, 40, &c. to 90, at the end on the right. In the first part of the line, the grand divisions each represent one degree, so that if each prime be sub-divided into 12 parts (as they commonly are upon sectors) each sub-division will signify 5 minutes. In the latter part of the line, the grand divisions which are each 10 degrees, being sub-divided into 10 parts, each sub-division will represent 1 degree, and according as they are again sub-divided into 4, 3, or 2 parts, such second sub-divisions contain 15, 20, or 30 minutes each.

3. What has been said of the line of fines, is likewise to be understood of the line of artificial tangents, whose divisions begin at 1, and is number'd 2, 3, &c. on to 10, in like manner as the fines, signifying single degrees; and in the second part it runs on with 20, 30, &c. to 45, which stands at the end of the line, then these return back again to 89 where the line begins, as would be evident from the inspection of the line itself, if it was number'd backward, as it ought to be, and in some that are large really are.

The use of these lines is in working proportions, whether arithmetical or geometrical; particularly they are of very ready service in trigonometrical solutions.

The method of working with them is thus: In all proportions you have three terms given, to find a fourth. Seek out therefore the first term, whether number, fine, or tangent, in its proper line; and on that point set one foot of your compasses, extending the other to the second, or third term, which-ever of them is of the same name with the first; the same extent laid from the other term, the same way, will reach to the fourth term required.

Thus to work the following proportion; as the fine of $52^{\circ} 30'$ to the number 85, so is radius, or the fine of 90° , to the fourth number required. Set one foot of your compasses in the line of artificial fines on $52^{\circ} 30'$, and extend the other foot to 90° on that line, the same extent will reach from 85 on the line of numbers to 107, the fourth number required. And thus are all

questions in proportion work'd by the artificial lines of numbers, sines and tangents; as will be more fully seen in the following section.

Observe, If the proportion to be taken is between two tangents, one greater, and the other less than 45 degrees, it must be taken by two extents of the compasses, viz. from the one to 45 degrees, and from 45 degrees back to the other; and these added, the sum is the extent from one to the other.

Of the manner of working Proportions on the Sector; both by the conjoint use of the Lines of Lines, with the Lines of natural Sines, Tangents, &c. as also by the artificial Lines of Numbers, Sines and Tangents.

Having already in treating of the reason, and general use of this instrument, shewn the particular use of the several lines of chords, sines, tangents, and secants laid down thereon, and how universal their application is thereby made, above what it is upon the plain scale: I now proceed to shew the conjoint use of the lines of lines, with the lines of natural sines, and tangents, as they are laid down sectorwise, and also the use of the artificial lines of numbers, sines, and tangents, in working proportions; which I shall exemplify in the resolution of the several cases of plain Trigonometry, both right angled, and oblique angl.d.

The

The Seven Cases of right-angled plain Triangles.

C A S E I.

The angles, and one of the legs being given, to find the other leg.

As suppose in the triangle ABC , the angle A is 36 degrees, and the base AB 75.4 feet, it were required to find the height of the perpendicular BC . Fig. 15.

The trigonometrical proportion for working this case; is as radius, to the tangent of the angle A , so is the leg AB , to the leg BC .

To work which upon the sectoral Lines.

Take with your compasses on either line of tangents, the tangent of 36° degrees laterally from the center; then open the sector to make this extent a parallel between 45 to 45 on the lines of tangents; now take with your compasses on the lines of lines, the parallel extent betwixt 75.4 and 75.4 the length of the given leg, which extent applied laterally from the center on either line of lines, will reach to 54.8, for the length of the other leg; so that the perpendicular BC , is thereby found to be 54.8 feet.

With the Beam-compass and sectoral Lines.

Set the beam-compass by the scale of 30 or 40 in an inch, at any multiple of the given leg, not exceeding the whole opened length of the sectoral lines,

lines, and open the sector to make it a parallel radius between 45 and 45 at the end of the lines of tangents ; then take the parallel extent between 36 and 36 in the said lines, and the compass scale will give the same multiple of the leg required, as was taken off the given leg.

Upon the artificial Lines.

Set one foot of your compasses on 45, or (the radius) at the end of the line of tangents, and extend the other backwards to 36 ; the same extent will reach on the line of numbers, from 75.4, the length of the given leg AB, to 54.8, the length of the required leg BC.

C A S E II.

The angles, and one of the legs being given, to find the Hypothenuse.

As suppose in the former triangle, the base AB as before 75.4 feet, the angle A 36 degrees, and consequently the angle C 54 degrees ; it were required to find the length of the hypothenuse AC.

Proportion. As the sine of the angle C, to the radius ; so is the base, to the hypothenuse.

To work which upon the sectoral Lines.

Take with your compasses the whole length of either line of sines, for the radius or sine of 90 degrees, (the quantity of the angle B) laterally from the center, and open the sector to make this extent a parallel betwixt 54 and 54 on the lines of sines ;

lines; then take with your compasses on the lines of lines, the parallel distance betwixt 75,4 and 75,4, the length of the base, and this extent laterally applied on either line of lines, will measure 93,2, the length of the hypotenuse sought.

With the Beam-compass and sectoral Lines.

Set the beam-compass by the scale of 30 in an inch, at 200 (or any multiple of 100) and open the sector to make this extent a parallel between 54 and 54 on the lines of fines; then take the parallel extent between 75,4 and 75,4, in the lines of lines, and the said scale will give the double (or other multiple) of the hypotenuse required.

Upon the artificial Lines.

Set one foot of your compasses on 54 (the fine of the angle C) in the line of fines, and extend the other to 90 at the end; the same extent will reach on the line of numbers, from 75,4, the length of the base, to 93,2, the length of the hypotenuse required.

C A S E III.

The hypotenuse and angles being given, to find either of the Legs.

As suppose in the foregoing triangle, the hypotenuse AC 93,2, the angle A 36 degrees, and consequently the angle C 54 degrees; and it were required to find the length of the Base AB.

Pro-

Proportion. As radius to the sine of the angle C, so is the hypotenuse to the Base.

To work which upon the sectoral Lines.

Set one foot of your compasses on the center, and extend the other laterally to 54 degrees on either line of sines; then open the sector to make this extent a parallel betwixt 90 and 90 on the lines of sines; now take the parallel distance between 93,2 and 93,2, on the lines of lines, and this distance applied laterally from the center on either line of lines, will reach 75,4, for the length of the base required.

With the Beam-compass and sectoral Lines.

Set the beam-compass by either scale at any multiple of the hypotenuse, near the whole length of the opened sectoral lines, and open the sector to make it a parallel radius between 90 and 90, at the end of the lines of sines; then take the parallel extent between 54 and 54, in the said lines, and the scale will give an equal multiple of the base required.

Upon the artificial Lines.

Set one foot of your compasses on 90 at the end of the line of sines, and extend the other backwards to 54, the sine of the angle C; the same extent will reach on the line of numbers, from 93,2, the length of the hypotenuse, backwards to 75,4, the length of the base required.

C A S E

C A S E IV.

The legs being given, to find the angles.

As suppose in the foregoing triangle, the base AB, as before, 75,4 feet, and the perpendicular BC 54,8 feet, it were required to find the quantities of the angles A and C.

Proportion. As the leg AB to the leg BC; so is radius, to the tangent of the angle at A: whose complement to a quadrant will be the angle at C.

To work which upon the sectoral Lines.

Setting one foot of your compasses on the center, extend the other laterally on one of the lines of lines to 54,8, the length of the perpendicular BC; then open the sector to make this extent a parallel between 75,4 and 75,4, on the said lines; the sector being thus opened, take with your compasses the parallel radius, or extent between 45 and 45, on the lines of tangents; then this extent taken laterally on either line of tangents, will give 36° , for the quantity of the angle A, and 36° subtracted from 90° , will leave 54° , for the quantity of the angle C.

With the Beam-compass and sectoral Lines.

Set the beam-compass by either scale at any multiple of the greater leg, near the whole length of the opened sectoral lines, and open the sector to make this extent a parallel radius between 45 and

45, at the end of the lines of tangents; then set the beam-compass to the same multiple of the lesser leg, and this extent taken parallelwise on the said lines, where the points will rest in like numbers, gives the lesser angle, and its complement is the greater angle.

Upon the artificial Lines.

Set one foot of your compasses on the line of numbers, in 75,4, the length of the base, and extend the other backwards to 54,8, the length of the perpendicular; the same extent will reach from 45 (radius) at the end of the tangents, to 36 the tangent of the angle A; and also to 54 the tangent of the angle C, if in the line of numbers, it had been taken forwards from 54,8 to 75,4; for (as before observed) the tangents should be number'd increasing backwards the same as forwards.

C A S E V.

The legs given, to find the hypotenuse.

As suppose in the foregoing triangle, the base AB is 75,4, and the perpendicular BC 54,8, it were required to find the length of the hypotenuse AC.

To work this Case upon the sectoral Lines.

Open the instrument to a right angle, (by Prob. the 18th on the uses of the lines of lines;) then taking between your compasses, the slant extent from 75,4, in one of the said lines of lines, to 54,8, in the other, apply the said extent laterally from the center,

center, on either of the said lines, and you will find 93,2, for the length of the hypotenuse required.

Upon the artificial Lines.

First, find the angles by case the 4th, then the hypotenuse, by case the 2d.

C A S E VI.

The hypotenuse and one of the legs given, to find the angles.

As suppose in the foregoing triangle, the hypotenuse A C 93,2, and the base A B 75,4, it were required to find the angles A and C.

Proportion. As the hypotenuse to the base, so is radius to the sine of the angle at C.

To work which upon the sectoral Lines.

Setting one foot of your compasses in the center, extend the other laterally on either line of lines to 93,2, the length of the hypotenuse A C ; then open the sector to make this extent a parallel radius betwixt 90 and 90, on the lines of sines ; again, setting one foot of your compasses in the center, extend the other laterally on either line of lines to 75,4, the length of the base A B ; this extent run parallelwise on the lines of sines, till the feet rest in like numbers, gives 54 degrees, the quantity of the angle C, opposite to the base, which being subtracted from 90, there will remain 36 degrees, for the quantity of the angle A.

With

With the Beam-compass and sectoral Lines.

Set the beam-compass by either scale at any multiple of the hypotenuse, near the whole length of the opened sectoral lines, and open the sector to make this extent a parallel radius between 90 and 90, at the end of the lines of fines; then set the beam-compass to the same multiple of the given leg, and this extent taken parallelwise on the said lines, where the points rest in like numbers, gives the opposed angle, and its complement is the other angle.

Upon the artificial Lines.

Set one foot of your compasses upon the line of numbers, in 93,2, the length of the hypotenuse, and extend the other backwards to 75,4, the length of the base; the same extent will reach from 90 at the end of the line of fines, backwards to 54, the sine of the angle C, and 54 subtracted from 90, leaves 36 for the angle A.

C A S E VII.

The hypotenuse, and one of the legs, being given, to find the other leg.

As suppose in the foregoing triangle, the hypotenuse AC 93,2, and the base AB 75,4, it were required to find the perpendicular BC.

To work this case upon the sectoral Lines.

Open the sector to a right angle, by *Prob.* the 8th. on the uses of the lines of lines; then setting one

one foot of your compasses in the center, extend the other laterally on either line of lines, to 93,2, the length of the hypotenuse AC; with this extent setting one foot in 75,4, the length of the base AB, on one line, the other foot will cut the other line in 54,8, the length of the perpendicular BC required.

Upon the artificial lines.

First, find the angles, by *Case* the VIth; then to find the length of the perpendicular, set one foot of your compasses on 90 at the end of the line of sines, and extend the other backwards to 36, the sine of the angle A; the same extent will reach on the line of numbers from 93,2, the length of the hypotenuse, backwards to 54,8, the length of the perpendicular required.

The Six Cases of oblique-angled plain Triangles.

CASE I.

Two sides, and an angle opposite to one of them, being given, to find the other opposite angle.

As suppose in the triangle ABC, the side AC being 65 leagues, and the side BC 54,1 leagues, and the angle A opposite to the side BC $35^{\circ} 30'$, it were required to find the quantity of the angle B.

Proportion. As the side opposite to the given angle to the sine of the given angle, so is the side opposite to the angle sought to the sine of the angle required.

L

T.

To work which upon the sectoral lines.

Setting one foot of your compasses on the center, extend the other laterally on either line of lines to 54, 1, the length of the side B C; then open the sector to make this extent a parallel betwixt $35^{\circ} 30'$, and $35^{\circ} 30'$ on the lines of sines; again, setting one foot of your compasses in the center, extend the other laterally on either line of lines to 65, the length of the side A C; this extent run parallelwise on the lines of sines, till the feet rest in like numbers, gives $44^{\circ} 15'$ nearly; for the quantity of the angle B, opposite to the side A C.

If you would know the quantity of the remaining angle C, subtract the sum of the angles A and B from 180 degrees (the sum of the three angles of every triangle) and the remainder $100^{\circ} 15'$, shall be the quantity of the angle C.

With the Beam-compass and sectoral Lines.

Set the beam-compass to any multiple of the side opposed to the given angle, not exceeding the greatest parallel between $35^{\circ} 30'$ and $35^{\circ} 30'$, on the lines of sines, and open the sector to make the said parallel fit thereto; then set the beam-compass to the same multiple of the other given side, and this extent taken parallelwise on the said lines, where the points will rest in like numbers, gives the angle required.

- Upon

Upon the artificial Lines.

Set one foot of your compasses on the line of numbers in 54,1, the length of the side BC, opposite to the given angle A, and extend the other to 65, the length of the side AC; the same extent will reach on the line of sines, from $35^{\circ} 30'$, the given angle A, to $44^{\circ} 15'$, the quantity of the required angle B.

C A S E II.

The angles, and one side being given, to find either of the other sides.

As suppose in the foregoing triangle, the side BC as before, being 54,1 leagues, and the angle A $35^{\circ} 30'$, the angle B $44^{\circ} 15'$, the angle C $100^{\circ} 15'$, the sides AB and AC were required.

Proportion. As the sine of the angle opposite to the given side, to the side given; so is the sine of the angle opposite to the required side, to the side required.

N. B. When an obtuse angle is given, you must work by it's complement to 180 degrees, which is commonly called it's supplement.

To work this case upon the sectoral lines.

Setting one foot of your compasses on the center, extend the other laterally on either line of lines to 54,1, the length of the given side BC; then open

the sector to make this extent a parallel between $35^{\circ} 30'$, (the angle A) and $35^{\circ} 30'$ on the lines of fines; the sector being thus opened, take with your compasses the parallel distance between $44^{\circ} 15'$, (the angle B) and $44^{\circ} 15'$ on the lines of fines, and applying the said distance laterally on either line of lines, it will give 65, for the length of the side A C. So likewise the parallel distance between $79^{\circ} 45'$, (the supplement of the angle C) and $79^{\circ} 45'$ on the lines of fines, will, when applied laterally on either line of lines, give 91,7, for the length of the side A B.

With the Beam-compass and sectoral Lines.

Set the beam-compass to any multiple of the given side, not exceeding the greatest parallel between $35^{\circ} 30'$ and $35^{\circ} 30'$ on the lines of fines, and open the sector to make the said parallel fit thereto; then take the parallel extent between the numbers of either of the other angles, on the said lines, and the scale will give the same multiple of the side opposed to the angle taken.

Upon the artificial lines.

Set one foot of your compasses on the lines of fines in $35^{\circ} 30'$, the quantity of the angle A, opposite to the given side B C, and extend the other to $44^{\circ} 15'$, the quantity of the angle B; the same extent will reach on the line of numbers from 54,1, the length of the given side B C, to 65, the length of the required side A C. Or, setting the first foot (as before) in $35^{\circ} 30'$ on the fines, extend

extend the other to $79^{\circ} 45'$, (the complement of $100^{\circ} 15'$ to 180°) the same extent will reach on the line of numbers, from 54,1 to 91,7, the length of the opposite side A B.

C A S E III.

Two sides, and an angle opposite to one of them being given, to find the other side.

As suppose in the foregoing triangle, the side A C being 65 leagues, and the side B C 54,1 leagues, and the angle A opposite to the side B C $35^{\circ} 30'$, it were required to find the side A B.

To work this case either upon the sectoral or artificial lines.

1. Find the angles, by Case the first.
2. The side, by Case the second,

C A S E IV, and V.

Two sides, and the contained angle being given, to find the other two opposite angles, and the other side.

As suppose in the foregoing triangle, the side A C as before, 65 leagues, and the side A B 91,7 leagues, and the contained angle A $35^{\circ} 30'$, it were required to find the other opposite angles B and C, with the side B C.

The proportion for finding the angles in this case is as follows, viz. As the sum of the two sides AC and AB, to their difference, so is the tangent of half the sum of the angles B and C, viz. $72^{\circ} 15'$, to the tangent of half their difference; which, added to their half sum, gives the greater angle C, but subtracted from the said half sum, leaves the lesser angle B.

N. B. The sum of the angles B and C, is found by subtracting the given angle A, viz. $35^{\circ} 30'$ from 180° .

To work these cases upon the sectoral Lines.

These two cases are taken together, because upon the sectoral lines it is most convenient to find the length of the third side, before the angles. To find therefore the length of the side BC, take the quantity of the given angle A $35^{\circ} 30'$, laterally on one of the lines of chords, and open the sector to make this extent a parallel betwixt 60 and 60, on the said lines; with the sector thus opened, set one foot of your compasses in 91,7 (the length of the side AB) on one of the lines of lines, and extend the other to 65 (the length of the other given side AC) on the other line of lines; this extent measured laterally from the center, on either line of lines, will give 54,1, for the length of the required side BC: Then may the quantity of either of the required angles be found by case the first, which added to the given angle, and the sum subtracted from 180, the remainder will be the quantity of the other angle.

With the Beam-compass and sectoral Lines.

Set the beam compass to the sum of the two given sides, or any multiple thereof, not exceeding the greatest parallel between the numbers of the half sum of the two opposite angles, on the lines of tangents; then set the beam-compass to the difference of the two given sides, or the like multiple thereof; and this extent taken parallelwise on the said lines, where the points rest in like numbers, gives the half difference of the two opposite angles, but if the line of quarter-tangents was taken with the line of the two sides, then multiply the difference of the said two sides, or it's multiple by four, and the half difference of the two angles will be given on the lines of the larger tangents.

Upon the artificial Lines.

First, to find the angles. Set one foot of your compasses upon the line of numbers in 156,7 (the sum of the sides A B and A C) and extend the other backwards to 26,7 (the difference of the sides;) this extent divided into two parts, one that will reach on the line of tangents from $72^{\circ} 15'$ (half the sum of the angles B and C) to 45° , the other part will reach from 45° back to 28° , which added to $72^{\circ} 15'$, gives $100^{\circ} 15'$, for the greater angle C; and subtracted from $72^{\circ} 15'$, leaves $44^{\circ} 15'$, for the lesser angle B. The angles thus found, the side B C may be obtained by case 2.

CASE VI.

The three sides being given, to find the angles.

As suppose in the foregoing triangle the side AB 91,7 leagues, the side AC 65 leagues, and the side BC 54,1 leagues, it were required to find the angles.

To work this case upon the sectoral Lines.

First, to find the angle A ; the two sides which include it, are AB 91,7 and AC 65 ; take the extent of the third side BC 54,1 between your compasses, laterally on either line of lines ; then set one foot in 91,7 on one of the said lines, and open the sector till the other foot falls on 65, in the other line of lines ; the sector thus opened, take with your compasses, the parallel radius, viz. the extent betwixt 60 and 60 on the lines of chords ; this extent measured laterally on either line of chords, will give the quantity of the angle A, viz. $35^{\circ} 30'$. The angle B may either be found by the same method, from the three given sides, or by the help of the discover'd angle A, according to the method laid down in case I.

The two angles A and B thus found, subtract their sum from 180° , the remainder will be the quantity of the third angle C.

With the Beam-compass and sectoral Lines.

Set the beam-compass by its scale, either to the base, or the sum of the two lesser sides, and open the sector to make the extent a parallel between the numbers of the sum of the two lesser sides, or of the base, on the lines of lines; then set the beam-compass to any multiple of the difference of the said two sides, by the same scale, or to the parallel extent between the numbers thereof on the said lines, and this extent will on the said lines, where the points rest in like numbers, or on the said compass scale, give the same multiple of the difference of the segments of the base, but in proportion to the sum of the said two sides. In this example, setting the beam-compass to $238.2 = 2 \times 119.1$, I open the sector, and make it a parallel between 91.7 and 91.7 in the lines of lines, now I take the parallel extent between 87.2 ($= 8 \times 10.9$) and 87.2 in the said lines, and the compass scale gives $226.5 = 16 \times 14.156 \times$.

Upon the artificial lines.

To work this case upon the artificial lines: First, divide the base, or longest side A B, into two segments, by a perpendicular let fall from the opposite angle C; the value of which segments are discoverable by the following proportion, viz. As the true base to the sum of the other two sides, so is the difference of the said two sides to the difference of the segments of the base: Which difference added to the true base, will give the

L 5 double

double of the greater segment ; but substracted, will leave the double of the lesser segment.

Set therefore one foot of your compasses on the line of numbers in 91,7, the length of the true base, and extend the other to 119,1, the sum of the two other sides ; the same extent will reach on the same line, from 10,9 the difference of the sides, to 14,157, the difference of the segments of the base ; which difference 14,157 added to the true base 91,7 gives 105,857, the double of the greater segment ; but substracted, leaves 77,543, the double of the lesser segment.

The triangle therefore being divided into two rectangled triangles, by the perpendicular, and the segments of the base thus found, the angles may be obtained by case the 6th of rectangled plain triangles.

I have now, I presume, pretty well exemplified the uses of the several lines laid down upon the modern sectors, tho' besides what I have mentioned, they are capable of very various applications, in mensuration, architecture, dialling, astronomy, &c. But as formerly other lines used to be put upon them, and still the *French* sectors are furnished with lines of superficies and solids, &c. and my Author too having in his *Practical Geometry*, treated of these two lines, which I there omitted, with reference to this appendix ; I shall here, from him, give the manner of their projection and application.

Projection

Projection of the lines of superficies.

Let the lines A E A E represent the lines of superficies, to divide which, having a scale of 1000 equal parts of the same length as the intended lines, take therefrom 125 parts *Fig. 17.* equal $\frac{1}{8}$ of 1000 *, which set off from the center A, as the first division upon each; 250 parts equal $\frac{1}{4}$ of 1000 set off from A, will be the fourth division; the mean proportion between 125 and 250, will be the number of parts marking the second division; the sum of 125 and 250 equal 375 parts taken from the scale, and set off from the center A, will reach to the ninth division; the third division will be the mean proportion between 125 and 375: again 625 parts will give the 25th division; and the mean proportion between 125 and 625, will be the fifth division, &c. lastly, 1000 parts will be the 64th division: All which is plain from the consideration, that similar surfaces are in a duplicate ratio of their homologous sides.

Use of the line of superficies.

Taking between the points of your compasses the radius of a circle, or the side of any plain figure, and setting it as a parallel betwixt 1 and 1, the first division from the center; so shall the parallel extent betwixt 2 and 2, give you the radius of a circle, or side of a figure of a double area; and betwixt 3 and 3 triple, &c.

In

* This supposes the whole length of 1000 equal parts to answer to 64, as in the figure.

In the same manner may be found circles, and other plain figures subdouble, subtriple, &c.

Projection of the lines of solids.

Let the lines A F A F represent the lines of solids: From the said scale of 1000 equal parts, set off from the center A 250, for the first division, and 500 for the 8th; then finding two mean proportionals betwixt 250 and 500, the first will give you the second division; and the second the fourth: To find this first mean proportional, subtract the logarithm of 250 from the logarithm of 500, and adding the $\frac{1}{3}$ of what remains to the logarithm of 250, you will get the logarithm of the first mean proportional, which will be nearly 315; and if you add again the same $\frac{1}{3}$ to the logarithm of 315, you will have the logarithm of the second mean proportional. For the third and ninth divisions, take two mean proportionals between 250, and the triple thereof, 750; and for the 5th and 25th divisions, take two mean proportionals between 250 and 1250, five times 250, &c. Lastly, the whole 1000 equal parts, will be the 64th division.



Use of the lines of solids.

Set over the side of any body, as a parallel betwixt 1 and 1, the first division on the lines of solids; and the parallel extent betwixt 2 and 2, shall give the homologous side of a similar body, whose solid content shall be double; and so the several other divisions will accordingly give sides of bodies triple, quadruple, &c. or sub-double, sub-triple, sub-quadruple, &c.

F I N I S.